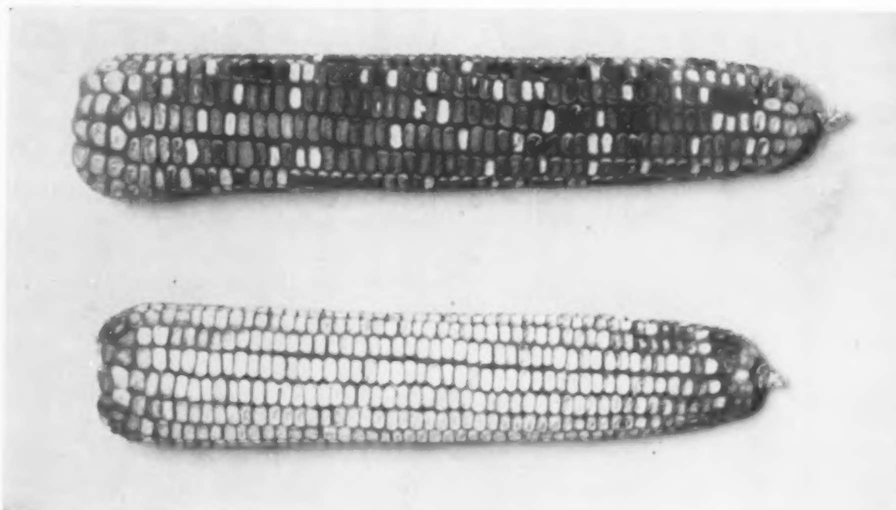
The American Biology Teacher

MARCH, 1961 VOLUME 23, NO. 3

Suggestions for Classroom Teaching

Study materials for

Genetics



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THE AMERICAN BIOLOGY TEACHER

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A Method for Recent Proposals

SOL CHARNEY, *123 Valentine Lane, Yonkers, New York*

The announcement last May by the American Institute of Biological Sciences adds urgency to the need for modifying methods of teaching so that they will be more compatible with proposed changes in the curriculum. Dr. John A. Moore of Columbia University, who is chairman of the Committee on Content of Curriculum of the Biological Sciences Curriculum Study, stated that "one of the principal goals of the program will be to give a more intellectual approach to biology teaching. Instead of concentrating on a 'parade of animal and plant life with endless names' there would be more emphasis on genetics, evolution, and historical development.

The writer submits that a method formally proposed by Professor James B. Conant[1] more than thirteen years ago is tailor-made for the BSCS's recommended changes in biology content. This is the *case history* method of teaching. At a glance, it has the proverbial advantage of "killing at least two birds with one stone." By employing this method, an understanding of both the historical development of biological sciences and subject matter can be gained at one and the same time. It would have the tremendous advantage of allowing students to relive and recapture great moments in the world of biology—not just to read about great events in a textbook as is widely done in the teaching of social sciences. In effect, empiricism, the distinguishing note in the study of natural science, would be given another dimension.

Use of the historical case method. This method actually enables the student to be engaged in studying basic research by going to primary source material of great biologists, repeating original experiments, and reforming basic concepts and theories. Then by identifying new problems brought into focus by the knowledge of the basic concept, and possibly formulating an original experiment to help solve one of the new problems, that phase of study can be brought up to date by the student. An entire course developed around these historical cases would, more than any other type of course, give the student an idea of how scientists work and how it really feels to be engaged in scientific endeavor. The BSCS's recommended topics of genetics and evolution lend themselves very well to this type of study. For the present, however, other topics which would round out the course in biology would have to be selected at the teacher's discretion. But no matter what topics are chosen under this approach, the general difficulties in modernizing a course would be overcome: there need be no sacrifice of basic facts and concepts in favor of current events; no upset of normal scope and sequence for the prevailing science curriculum; no reason for gifted students not advancing further and more rapidly. In addition, this type of course has the benefit of not being put into a straight jacket by any single textbook.

The judicious selection and development of historical cases within the broad topics to be studied is absolutely necessary in such a course. It still remains to be determined, for example, if Pasteur and his work would provide the best historical case for the topic of microbiology; Pavlov for behavioral science; Goldberger for nutrition, or just who should be selected for the various topics and exactly how the case histories could best be organized for teaching. The writer does feel, however, that not much more than six case histories should be contemplated for study in a year course. This would allow approximately six weeks for each unit of study and provide ample time for the enrichment needed in such a course.

To show what is meant by this approach, a very brief overview of a unit taught by this method is here presented. In teaching a traditional unit in genetics the class would actually *study* source literature such as Mendel's "Experiments in Plant Hybridization"; the class would actually repeat the original experiments with garden peas and reformulate the basic laws of genetics by themselves. Then the

[1]Conant, James B., *On Understanding Science, An Historical Approach*, Yale University Press, New Haven, 1947.

class would proceed further by studying source material from such scientists as Morgan, Blakeslee, Muller et al., and actually repeat and verify fundamental experiments with fruit flies, colchicine, X-rays and the like. If an X-ray source is not available in school, the dentist's office is a good place to find one. From this avenue the learning could be extended to more recent concerns in the field of human genetics such as the effect of radioactive fall-out. A further extrapolation of the study to the new vistas and problems revealed by the findings of these scientists, such as the genetic basis of evolution, can help to develop a logical sequence for the course and broaden the scope enough for this level of learning.

Efforts to develop case histories. Efforts are being made to develop "history of science cases" for teaching secondary science. For the past several years, Mr. Leo E. Klopfer at the Harvard University Graduate School of Education, has been attempting to develop a series of History of Science Cases for High School. The History of Science Cases thus far developed include three each for biology, chemistry, and physics. Briefly, those outlined for biology are:

1. *The Sexuality of Plants*—follows the development of this concept from ancient times and culminates with the founding of the Linnaean System.
2. *Frogs and Batteries*—Galvani's observation of "animal electricity" is corrected by Volta, who devises a new tool later used in biological research.
3. *The Cells of Life*—Formulation of a major theory by Schleiden and Schwann.

The United States Office of Education has demonstrated interest in this method of instruction by underwriting an evaluation project for the "History of Science Cases Instruction Method" during the 1960-1961 school year. The writer is one of a number who has volunteered to aid in this forthcoming evaluation study.

Although the "History of Science Cases" outlined by Mr. Klopfer are not exactly like the "Historical Cases" presented by Prof. Conant, they are both basically similar. They are both intended as a method of instruction by which students themselves will re-establish basic scientific concepts and facts, and at the same time be inculcated in an appreciation of the scientist and his work, i.e., the *scientific method*. Up to the present, as far as is known, no attempt has been made to teach an entire academic biology course in the secondary school by this method. In view of the recent trend of suggestions for curriculum changes and the advantages outlined in this article, the writer is of the opinion the *historical case method* of teaching is definitely worth more practical recognition in the classroom at this time.

Memory

The ability to remember appears to be spread throughout the bodies of worms used in a series of experiments at Washington University, rather than concentrated in the brain.

This is the conclusion of Edward N. Ernhart, graduate assistant in psychology of the College of Liberal Arts at Washington University of St. Louis, who has been testing the learning retention of planaria. Ernhart taught the worms, which dislike light, to crawl through a maze to a dark, sheltered area. After they learned the route to the darkness, he cut them across the center, placing the two groups in separate containers while the heads grew new tails and the tails, new heads.

After they had regenerated, he again placed the animals in a maze and tested them to see which group relearned most quickly. He found that the group which had grown new heads remembered as well as did the group possessing the original head and brain. He tested the behavior of his sectioned worms against that of two control groups, worms which had been trained to crawl the maze but were not sectioned, and worms sectioned without prior training in maze crawling.

Ernhart says his experiments seem to suggest that much learning retention, particularly retention involving motor skills, is on the level of the individual cell, rather than centralized in the brain. He says it is hard to say what implications the tests have concerning learning on the human level, because of the difficulty in projecting data from the level of planaria to that of human beings.

A Review Method for Courses in Biology

ARTHUR W. GLASS, *Gustavus Adolphus College, St. Peter, Minnesota*

When one studies a course such as general biology he encounters a multitude of scientific names and terms and is, indeed, forced to learn a new vocabulary. This is necessary if one is to be able to converse in his field, write a term paper or to read efficiently. The words of this new vocabulary are learned through repeated usage, and the mastery of them seems, at times, to be an insurmountable task to the student.

There are many ways in which a teacher might "force" a student to acquire such a vocabulary. The cross-word puzzle combines work with pleasure. However, one would need far too many puzzles in order to have the required amount of repetition. The number of terms which may be presented is, of necessity, very small. The average laboratory manual contains a great many blanks which must be "filled in," and terms must be defined or discussed. Once again the much-needed repetition is found to be lacking.

Several years ago the author gave serious consideration to developing some review process which could be easily checked; which allowed a repeated presentation of terms, facts and concepts and which would be of benefit to the student. The "system" is simple, has proved to be a success, and might be of value to certain teachers of biology who have a need for this type of material.

The "system" requires a sheet or sheets on which questions are to be found, a sheet on which the answers to the questions are to be found, and a standard-form answer sheet which the student must complete. The first two are stapled together in booklet form. This booklet, once it has been prepared may be used year after year or as long as the instructor desires. This booklet should be considered to be the property of the department and should be returned by the student.

The question sheet deserves some special comment. Since all of the questions are to be answered by a word or phrase the instructor should make the question as informative as possible. Instead of asking, "Which of the enzymes found in the gastric juice is involved in the digestion of protein?" one might combine certain information with the question. The following is an example: "Enzymes, which are protein in nature, catalyze the hydrolysis of foods. What is the name of the gastric enzyme involved in the digestion of protein?" There is, of course, no limit, other than a practical one, to the amount of information which can be included in the question.

The preparation of the sheet on which the answers are to be found is simple. Our sample contains nine columns each headed by a different letter of the alphabet. One would normally use the letters "a" through "i." Beneath each alphabetical heading nine answers are to be found. Note the example which follows.

"a"	
1. hydrolysis	5. dextrins
2. pepsin	6. polysaccharides
3. chymotrypsin	7. dehydration
4. maltase	8. fatty acids
	9. amino acids

Nine different answers would be found under the heading "b," nine under "c," and so forth. There is nothing magic about the number nine, but there are certain limitations imposed by the standard-form answer sheet.

The standard-form answer sheet is prepared in the following manner:

Name________ Course________ Review sheet #___

______ a b c d e f g h i __________________
1 2 3 4 5 6 7 8 9

______ a b c d e f g h i __________________
1 2 3 4 5 6 7 8 9

The average answer sheet will have thirty of these letter-number combinations. The blanks preceding the letters will be filled in with the number of the question. This is done by the student. If one asks more than thirty questions, two answer sheets must be given to the student. The blanks following the letters are for the written answers to the questions. Recall that the answers consist of one word or of short phrases. The answer sheet should be prepared in such a manner that as much space as is possible is provided for the written answer.

If we use our sample "informative question"—"Enzymes, which are protein in nature, catalyze the hydrolysis of foods. What is the name of the gastric enzyme involved in protein digestion?"—and consider it to be question number one, the student would follow this procedure. He would first write the number *1* in the blank in front of the first letter-number combination. He would then search for the answer on the sheet which contains them. The answer will be found under one of the alphabetical headings. If we use the column of answers which we have given in this paper, the correct answer is "a"-2. The student would then encircle the "a" and the 2 and then write the word pepsin in the blank which follows.

The instructor may alphabetize all answers under each heading or he may alphabetize all answers on the answer sheet if he so desires.

A valuable characteristic of this type of review system is the ease by which the answer sheets may be checked. The instructor punches out all of the correct letters and numbers on a master answer sheet. This may be done with a cork borer of the correct diameter. The master answer sheet is then placed over the student's answer sheet. Any punched-out hole in the master which has not been encircled by the student represents an incorrect choice by him. If the instructor makes a mark in such holes each mistake made by the student will be readily apparent to him.

The answer sheets may be graded if the instructor so desires. One must realize, however, that a student may easily copy the answer sheet of another student. This is an inherent weakness in the case of most types of homework. However, if the instructor uses a testing system based in whole or in part upon the review sheets it will soon be obvious to the student that they serve a definite need.

Each review unit should be so designed that it contains a great deal of material which has been covered in the preceding unit. In this way much of the material will be repeated again and again and this repetition of words and phrases will aid in the mastery of the mountain of biological vocabulary.

BSCS Films

Three short 16 mm. films, concerned specifically with basic biological laboratory techniques, have recently been released by BSCS and the producer, Thorne Films. Already in use in the BSCS teacher-training program, the films are also effective teaching aids for use at the high school level.

The longest of the three sound-color films runs for 5 minutes. Entitled *Bacteriological Techniques*, the film illustrates making cotton plugs, flaming a wire loop, transferring culture from tube to tube and from tube to flask, pipetting, preparing agar plates, spotting, streaking, picking up cover slip by hanging drop, and forming a microculture chamber.

Genetics: Techniques Handling Drosophila is a 3 minute film showing the fundamental equipment needed for maintaining colonies of flies and the techniques used in etherizing, sorting, re-etherizing, and transferring stocks. The third film is a remarkably concise one-minute demonstration of how to locate, identify, and remove a frog pituitary. It is titled *Removing Frog Pituitary*. A teacher's guide is furnished with each film.

Assuring maximum flexibility and usefulness to teachers, the films are offered three on one reel, singly, or as a set of three separate short reels. Orders may be placed only through BSCS, McKenna Building, University of Colorado, Boulder, Colorado.

Air Attack on Forest Fires

A 32-page beautifully illustrated booklet has just been issued by the Forest Service of the U. S. Department of Agriculture on this topic. Copies may be obtained from the Superintendent of Documents, Washington 25, D. C., for 30 cents.

NSTA Annual Meeting

The National Science Teachers Association will hold its annual meeting in Chicago, March 24-29, with headquarters in the Hotel Sherman. Over four hundred speakers are scheduled for the meeting, and they include Nobel Laureate, Glenn T. Seaborg; James F. Crow, Hugh Odishaw, and Paul E. Klopsteg.

The 6th Sense—Nonsense?*

THOMAS G. OVERMIRE, *Shortridge High School, Indianapolis, Indiana*

Sometime during the discussion of the unit on behavior and the nervous system, some student invariably brings up the subject of the so-called "Sixth Sense." It may appear in the form of a question about extra-sensory perception, mind-reading ability, or what have you, but the idea of a sixth sense will be involved. Class interest always picks up here because every student can remember a time when he started to phone a friend and discovered that his friend was trying to call him at the same time. Or he can remember the time he dreamed that his aunt from California was coming for a visit, and she came. Some students will insist that these occurences are pure coincidence. Others will feel that more than coincidence is involved . . . something mysterious . . . like our sixth sense.

In discussing the question of coincidence vs. sixth sense, an understanding of the laws of chance is fundamental. If students have already been exposed to exercises involving standard deviation, chi square, or random distribution, the problem is simplified. Too frequently, however, my students do not show signs of remembering these ideas from one unit to the next. Consequently, I find it necessary to approach the question by developing four basic rules. While recognition of these rules may not settle any arguments or answer any specific questions, it will, at least, offer a starting place for a scientific analysis of sixth sense phenomena.

To develop the first general rule the class is asked, "If a person has four choices in a situation, how frequently should someone else be able to predict which choice will be made?" After some discussion the class usually agrees that: (1) a person should be correct in about one-fourth of the predictions, and (2) anyone who can predict correct answers 50% of the time must have some mind-reading ability. To demonstrate *my* ability to do just this (i.e. read minds) I have each class member list the numbers 1 through 4. Then, without comparing answers, each person is directed to circle one of the numbers. It is explained that in order to save time I shall read everyone's mind at the same time. After careful concentration I announce the numbers selected. The prediction is the same for each person—number 3. For some reason it always turns out that from 60% to 70% of the class will have chosen this number. There are probably several explanations for this, but the fact remains that it does happen this way.[1] Therefore, if an accurate analysis is going to be made of any problem involving a sixth sense concept, it is important to recognize that similar quirks may be at work. We have now arrived at the first general rule:

Be aware that unaccounted-for factors may be involved.

Someone usually suggests, either voluntarily, or subconsciously through my "mental direction," that if symbols rather than numbers are used these unaccounted-for factors may be avoided. This allows me to develop the second general rule.

For this second rule, some member of the class is chosen to be a "thought leader." He is asked to concentrate on one of a series of four abstract symbols. The class is then instructed to try to predict which symbol he has chosen by bringing their thought waves "in phase" with his. After the students have recorded their choices, another, or the same, symbol is chosen for a second trial. After twelve trials are completed the results are checked. Three correct answers may be expected through chance. Since some of the students may have seven or more correct answers it may seem to prove that these students are more receptive to thought waves than are their classmates. When, however, a second or third series is conducted, and the same high percentages are not maintained by the same students, the second general rule becomes apparent:

In order to be able to interpret results

*The author is now teaching at Ball State Teachers College, Muncie, Indiana.

[1]Of course, if I were to make a second prediction it would be strictly a guess, and the results would verify this.

accurately a large sample must be considered.

To develop the third rule I suggest that I can project my mindreading ability to one of the class members.[2] To test my boast the class chooses some student to be my aide or Swami. It is important that the class makes the choice so that there can be no suggestion of collaboration. While the blindfolded Swami sits at the front of the room, objects are selected for him to identify. I guide his thoughts by asking questions such as: "Swami, how many pencils do I hold in my hand? If you answer correctly I shall give you both of them!" or "Swami, what is the date on this coin? What is the date on this coin? I repeat, what is the date on this coin? Come now, do I have to ask you 19 or 23 times, what is the date on this coin?"

After a few of these questions some of the students begin to question my technique. Having made the point, I concede that although more subtle methods might be in order, we nevertheless have established the third rule:

Always be aware that you may be the victim of a hoax.

The fourth rule evolves when I attempt to hypnotize the class. From the outset I insist that I will not really be able to hypnotize them, but I suggest that the demonstration may show which students could be hypnotized if I actually were a hypnotist. I note that I shall not have any success if they decide that they do want to be hypnotized. I try to convince them that being able to resist my "power" is no great feat since I cannot hypnotize people anyway. Usually, through this line of persuasion, the cooperation of the majority of the class is obtained.[3]

To achieve the "hypnosis" each student is told to clasp his hands before him with his fingers entwined. After a moment of quiet talking to settle down the gigglers the students are directed to close their eyes and to concentrate on their clasped hands. They are told that if they concentrate hard enough they will feel their hands flow together . . . their fingers will almost seem to fuse and they will not be able to separate their hands. It is then suggested that they try to pull their hands apart.

This is the extent of the "hypnosis." Yet, some of the students always admit that they could not separate their hands. I suggest that while this does not mean that they were under hypnosis, it does mean that it is sometimes possible to talk people into believing things that are just not so. This gives us the fourth rule:

Realize that judgment is always susceptible to being swayed by emotions or convincing words.

The class now has a set of rules with which to analyze unusual occurrences. No definite yes or no answers have been given, but some suggestions have been advanced as to conditions that might cause biased interpretations.

The response of the class to the whole procedure is varied of course, but there is a basic fascination about sixth sense phenomena that can be exploited to perform a scientific service. No profound concepts have been developed, but if new ideas have been revealed the time has been well spent.

[2] This usually receives a somewhat less than 100% endorsement.

[3] This means that the "nonbelievers" agree to keep their comments and laughter to themselves as much as possible.

Local Periodical

A very fine monthly, *The Reporter*, a newsletter for science and math teachers, is published by the Joint Board on Science Education for teachers in the Washington, D. C., area. The eight-page newsletter is a very fine help to science and mathematics teachers, and it is a fine evidence of the very good cooperation which science and mathematics receive in this area from local organizations. The Joint Board on Science Education is located at 1530 P Street, N. W., Washington 5, D. C.

Film Bibliography

The Audio-Visual Center of Indiana University has just published a catalog of "Films for Junior and Senior High School Biological and Physical Sciences." It is an eighty-six page bulletin listing all of the films that are available from the Audio-Visual Center in the sciences. It may be obtained by writing the Center.

The Biology Classroom Extended

CHARLES H. BUTTERFIELD
Bethesda-Chevy Chase Senior High School, Bethesda, Maryland

Fred was discussing the effects of vitamin deficiencies with our class in first year biology. The cases he reported were routine and well-known to the rest of the class. The real spark in the conversation came from Lee who had read that certain fat-soluble vitamins could be stored in the body with rather serious consequences. I had not expected this phase of the subject to be introduced, and the rest of the class was visibly stimulated by the idea. This kind of enrichment would not have come from me, but I have learned to expect it in my classes recently.

I have found a way to provide for the enrichment of biological subjects which I think has been ignored too long by biology teachers. Extend the biology classroom into the school library. As a result of varied library assignments, I have observed a great improvement in the quality of our class discussions. It was from a library assignment that Lee had discovered the effects of an overdose of vitamins.

Providing for the enhancement of my biology classes has always taken up much of my time. Now the burden has shifted to the students, where it belongs. I have found several ways to use our library facilities to broaden and deepen the scope of high school biology.

The idea to use the school library was suggested to me by a librarian, and I have found our school librarian most enthusiastic about the increased usage of this facility by biology students. Here are the library activities that I would suggest to other busy biology teachers:

One, assign analytical reports of magazine articles on subjects inadequately treated by the basic text or supplementary reference books. In addition to increasing the child's concept of a given subject, the improved ability to read, interpret and report are inevitable, valuable outcomes. Take the class to the library and teach them the use of the *Reader's Guide to Periodical Literature* in finding recent articles. In a world of frightening technological advances, the ability to keep abreast of the sciences becomes a necessity. The ability to do this with a critical eye must be practiced as much as the manipulation of the microscope.

Second, assign book reports. One or two such reports a year will serve to introduce the students to the fascinating books about the biotic world. Never before have there been available to the lay public so many well-written books explaining biological investigations. Yet students of biology may be quite unaware of this if assignments are not made that bring these books to their attention. In spite of the advances made in communication, nothing has replaced the well-written book. Children must be at ease with books even if they see them only as supplements to TV! This writer has a short list of popular biology books suitable for the high school student which is available to interested teachers.

Third, suggest that your students investigate the pamphlets, reprints, and bulletins which are available in the vertical file of the library as a source of project ideas and definitive explanations of topics. It follows that biology teachers must assist the librarian in obtaining this material from its many sources. The Government Printing Office, the various learned societies, and certain industrial organizations are three sources from which free or inexpensive publications may be acquired for the vertical file.

Fourth, set up an overnight reserve shelf where books that will assist in homework assignments are easily accessible. Just learning that the library is a good place to find information for biology assignments is a major awakening to many students. A need to improve the students' appreciation of the library is a sad commentary on our society. It is a need that the biology teacher can and must help to fulfill. To paraphrase from the motion picture industry—libraries are better than ever!

The biology classroom extended? Yes, and naturally so. The college preparatory students must be trained in the use of this extension of the biology laboratory. The terminal students, who become part of the voting

and consuming citizenry, must know where and how to find information to solve problems in daily living.

The rewards to the students are many and varied. The rewards to the biology teacher are gratifying and inspirational. The teacher's share of the burden of enriching the biology course will be vastly lightened by extending the biology classroom in the direction of the school library.

Biology in the News

BROTHER H. CHARLES, F.S.C.

THE BATTLE TO SAVE THE TREES, Charles Ogburn Jr., *Saturday Evening Post*, January 28, 1961, pp. 28-29, 68-70.

Subdivisions occupy more and more of the land around cities. Little is done to preserve valuable topsoil and native vegetation. The author presents the seriousness of the situation and offers some solutions.

OUR NATIONAL PARKS IN JEOPARDY, *Atlantic Monthly*, February 1961, pp. 45-60.

RESORTS OR WILDERNESS? Devereux Butcher.

NATURE OUT OF BALANCE, Clark Van Fleet.

THE PRESSURE OF NUMBERS, Paul Brooks.

This group of articles are reading for your better students but contain information which should be called to the attention of all. How should our national parks be handled so eager visitors may enter and yet preserve the regions for the purposes for which they were originally set aside? Laws and rangers are necessary but only intensive education will be effective in solving the problem.

THE JAGUAR, Jack O'Connor, *Outdoor Life*, February 1961, pp. 52-55, 147.

An interesting account of the largest of America's spotted cats; their habits and life history.

HOPE IN A BITTER TEEN-AGE TRAGEDY, Herbert Brean, *Life*, February 10, 1961, pp. 97-104.

Alcoholism affects more than those afflicted with the disease. This health problem needs to be discussed. The account of some workings of Alateen groups can be used to stimulate discussion.

WHAT DO YOUR BLUE CROSS AND BLUE SHIELD REALLY COVER? *Good Housekeeping*, February 1961, pp. 72-73, 204-209.

Too many people never read what is actually covered by their insurance policies. Discussion initiated by reading this article can have profitable results for students and their parents.

900-CALORIE DIETS: MIRACLE OR MENACE? *Good Housekeeping*, February 1961, pp. 148-149.

Liquid diets are now the fad of many people. Such diets result in loss of weight, but can they be used safely over any considerable period of time. The article maintains that they are safe only when supervised by the family physician.

Allergy

A new advance in allergy research, promising to ferret out the culprits in grass pollen that causes hay fever, was reported by three chemists of Gonzaga University. The researchers, Dr. Donn Herron, Dr. Arthur McNeil, and Dr. G. H. Stewart, described a unique application of a method called partition chromatography. The technique makes use of a vertical tube packed with a cellulose resin at a carefully-adjusted acidity, according to the report.

The isolation of the active agents in pollens is essential for identification and the development of medications to counteract the allergy. Because of extremely complex structures and unstable natures of the active allergy agents, isolation has been a major problem.

The Gonzaga University chemists said that their separation method, utilizing to a fuller extent equipment already in use, results in active agent solutions of a purer content than previously possible.

Techniques for Developing Interest in Senior High School Biology

VERNANCE BESTE, *Walter Johnson Senior High School, Rockville, Maryland*

The textbook has been and probably will always be an essential aid to learning. In too many schools the textbook is the course in biology, and learning consists in reading the text and reciting the contents back to the teacher. Such abuse of the textbook method results in lack of interest on the part of the students. Properly used, textbooks may become a very integral part of a course in biology. If a single basic text is used as the sole reference source, students will think of the text as the only source of information. A single basic text may be used to supply the pattern of development and other texts and references used in a supplementary way.

Most texts have workbooks to accompany them. Many of these workbooks have an adopted form which consists of questions, the specific answers of which are found in corresponding chapters of the text. The workbook should supply references to text material upon the same subject but not to the specific answers. The fact that a workbook is not prepared for a particular text may be a decided advantage. The questions should be problem-solving in nature and should call for the application of facts learned from reading and observation rather than just mere facts. Instead of spending class time in answering these questions, students should be examining materials, recording observations from experiments, etc. Some workbooks contain tests which are not diagnostic in nature and as a result may not be of much value. Workbooks which avoid some of these objectionable features may have considerable merit. Workbooks sometimes contain procedures for laboratory work. A good laboratory manual is a very useful educational instrument.

In addition to the basic text and supplementary texts, I have posted on the bulletin board in the classroom a list of books and magazines pertaining to biology which are available in the public and high school libraries. Toward the rear of the classroom is a reading table which supplies information relevant to the unit of work being studied. Some of this material is from the library and a great deal of it has been collected by students. Current science magazines such as *Nature, Natural History*, and *Science Newsletter* are also available here. Not only on the reading table but also on the bulletin board current science materials from newspapers and magazines are placed. Much excellent teaching material accumulates from year to year. Many teachers find that an ordinary filing cabinet is an efficient way of indexing and storing such material for future use.

As most people realize, learning is not confined to the classroom. The modern biology teacher uses the resources of the community to enrich and supplement learning in the classroom. In the fall and/or spring, field trips can be taken to observe and study the plants and animals of the area. It is a technique which gives pupils first-hand experiences with phenomena which cannot be brought into the classroom. It is the only technique which makes it possible for students to see plants and animals in their true relationship to each other and to their environment. Field trips near the school can be conducted during the regular recitation period. Many teachers fail to see the materials which are close at hand and possibly have not learned how to utilize them in their instruction. In the study of trees, shrubs, and vines I have found that a simplified key is very helpful and can easily be followed by the majority of students. Some journeys require an entire day.

If field trips are not feasible, audio-visual aids can be used as substitutes for these first-hand experiences. In our school system we have a film library which contains school owned films, 16 mm. sound projectors, filmstrips, slides, filmstrip and slide projectors, opaque projectors, records, phonographs, tape recorders, microphones, etc. An audio-visual club has charge of dispensing and operating the equipment. There are many excellent films in the field of biology. There are some phonograph records that are particularly pertinent to biology. A microprojector is a valu-

able piece of equipment in a biology room. One of the greatest advantages of this instrument is the fact that microscopic specimens may be projected on a screen where an entire class can be shown the subject matter, and various important parts can actually be pointed out by the teacher. It speeds up the study of microscopic work tremendously and arouses a great deal of interest. It eliminates cramped position, eye strain, and the uncertainty about what the student sees.

The teacher should not overlook the possibilities of amateur photography as an aid to teaching biology. In ninth grade general science there is a unit on photography in which students learn how to take pictures and develop their own film. In biology they can make use of this information by taking colored slides and movies of plants and animals which they can later show to their class.

Experiments offer an opportunity in science for collecting information. Experiments help students to reason logically and cultivate proper habits of thought. Every experiment should contribute toward the solution of a problem. The science laboratory is a natural place for pupils to engage in problem-solving activities Many experiments can be performed in biology such as—Do plants give off carbon dioxide? Do green plants produce starch in photosynthesis? Do leaves of plants give off water? etc.

Live animals for observation are of great interest to the students. Pupils learn a great deal about life habits of animals by observing and caring for them. Some laboratory animals that we have had in the past would include—tropical fish, fish of our native waters, frogs, crayfish, common toads, snails, clams, horned toads, fence lizards, chameleons, salamanders,

newts, turtles, fairy shrimp, mud puppies, alligators, birds, squirrels, young fox, chinchillas, hamsters, and other rodents. Last spring students observed the hatching of baby chicks. Some students may be interested in making an incubator. Other students may choose to have their own aquarium of tropical fish. Raising guppies is a very interesting and worthwhile hobby. Some students may have their own pet squirrel, rabbit, raccoon, etc. They would probably be interested in constructing cages for these animals. Similar projects might include the making of mammal traps, bird houses, feeding stations, and the like.

One of the chief aims of biology teaching is to make students intimately acquainted with the nature of the world in which they live, to teach them to understand and appreciate the interrelationship between man and his environment. Students cannot gain such appreciation and understanding by merely reading about it. Observing plants and animals in their natural surroundings is the ideal way to gain knowledge. When this is not possible, it becomes important that we bring the outside world into the classroom or laboratory. This can be accomplished by collecting specimens which will motivate and vitalize the subject matter. There is a great variety of specimens that can be collected by students: various types of plants, insects, fish, amphibians, reptiles, birds, and mammals. Collecting specimens and bringing them back to the laboratory adds interest to the work. The specimens after they have been observed and studied by the pupils should be preserved and made a part of an ever-growing biology museum.

There are various methods of preserving specimens. Specimens such as fish, amphibians, and reptiles can easily be preserved in formalin. There is a simplified method we use in making study skins of birds, rodents, and other small mammals. This method does not necessitate the removal of internal organs and as a result is very time-saving. Simply mix equal portions of formaldehyde and water. The amount will be proportionate to the size of the specimen. Inject this solution into the body of the animal. The cranial cavity can easily be injected through the eye socket. Each limb should be injected separately from the trunk of the body. If the animal is large, several injections may be necessary in the region of the trunk. The digestive system can best be injected through the anus. The animal is then left in the desired position to harden. A saturated solution of sodium arsenate and formaldehyde can also be used in place of water and formaldehyde. This should be used with great caution because it is highly poisonous. After injection birds can be placed in cylindrical celluloid containers which will permit extensive handling with little or no damage to the specimen. Specimens such as these will last for years. A realistic mount of a specimen can also be made. If this is done, the internal organs should be removed. In the past I have mounted several specimens, but for the average teacher time does not permit any extensive work of this nature. Instead I send out the larger and less common specimens to a local taxidermist for mounting. We have many shelves filled with mounted specimens not only in the biology classroom but also in the general science rooms. Some time ago one of my students became very interested in taxidermy work. The animals which he mounted were on display in the fish and wildlife building at the local county fair. The preparation of animal skeletons is also of interest to some students.

Models, charts, diagrams, and pictures have two types of uses. They may serve as substitutes for specimens or they may be constructed by the students as aids to their understanding. It need not be undertaken by all students. Models have the advantage of depicting objects in three-dimensions. The biocast method employs a newly developed type of plastic mold for making three-dimensional biological models. The student simply mixes ordinary Plaster of Paris with water and pours the mixture into the biocast mold. When the plaster has hardened the model is taken out and the mold is ready to be used again. Hundreds of casts can be made from a mold. Using either tempera, water colors, oil paints, enamels or lacquers, the student colors his model. If tempera is used a figurine glaze should be painted or sprayed over it to prevent the tempera from rubbing off. I find that the biocasts provide purposeful, enjoyable, and meaningful learning experiences. During the past year one student used Plaster of Paris to make a display depicting the age of reptiles. He used a wooden box in which he poured the Plaster of Paris. While the Plaster of Paris was in the process of hardening, he placed air-ferns in it to represent tropical vegetation and suspended, via wire, a model of an ancient bird. He used models of dinosaurs to make footprints in the terrain. After the Plaster of Paris hardened he painted it with tempera and glaze to distinguish land from water. This project was not only used in biology but also in the elemen-

tary grades and was on display in the public library.

Good charts and diagrams can be of value in assisting the student to gain concepts that are impossible from words alone or even difficult to obtain from specimens. During the course of the school year students dissect such organisms as the earthworm, grasshopper, crayfish, fish, frog, etc. Drawings of these and other animals and plants can be made very effectively on white tagboard. The outline of the organism can be made with india ink directly on the tagboard. Colored transparencies can be made to fit over this outline. The organs can be painted on sheets of acetate with airplane dope. If the organism is quite complex in structure, a sheet of acetate might be reserved for the purpose of representing each system, separately. As a result of this type of diagram students can see the chief organs from front and back views. Students can also study each organ in relation to the other organs and see how the various systems are related to each other. Comparisons can also be made between simpler organisms and more complex organisms. In addition, the three-dimensional depth allows the student to see organs lying under other organs. A numbered key to all the organs shown can be placed in one corner of the tagboard. It will serve as a summary to check students' knowledge of the names and locations of the chief organs. The blackboard can also be used for charts and diagrams. Colored chalk can be used very effectively to distinguish parts of an organism. The hesitancy of teachers to use the blackboard is usually based upon a feeling of modesty because of a lack of artistic ability, but such drawing should be purely diagrammatic, not artistic. Tagboard can also be used to display pressed specimens of plants such as flowers, weeds and leaves of trees. Many plants can be mounted on one sheet if each plant is placed on a small piece of tagboard covered with acetate. These can be mounted one under the other with each specimen in partial view. Upon closer examination every specimen can be viewed separately. Each student can construct his own plant press by using a discarded peach crate strapped together with pieces of corrugated cardboard between to absorb the moisture from the plants and allow air to pass through freely. The plants can be placed between the cardboard on sheets of newspaper. A display of plants for the classroom can be made quite simply. In our school a discarded cabinet with a glass door was cut down to about a four inch depth. In it several layers of cotton were placed with a piece of white flannel over the top. Specimens were mounted directly on the flannel with Elmer's-Glue-All, a very strong glue, quick setting and dries clear. Beneath each specimen was the name of the plant typed on a piece of paper. The glass door closed over the top of the specimens helping to hold them securely in place. This display was later hung on the wall and serves as a guide to students in their work. We have a similar display of insects.

By discussing a few of the many techniques which can be used in teaching biology I hope that I have in some way contributed to help the beginning teacher or the teacher who really wants help in developing student interests in biology.

Foreign Service Posts

Two openings are now available for biology teachers in Greece and Lebanon. They are: Anatolia College, Thessaloniki, Greece. This opening is for a single woman to teach biology, zoology, and botany, at secondary and junior college level. M.S. in zoology or physiology and good teaching experience is required. Research experience is desirable. And, American University of Beirut, Lebanon. The opening is for an Assistant or an Associate Professor. Teaching and research will be in genetics, organic evolution, and ecology, for juniors and general biology for freshmen. Ph.D. with teaching and research experience is required.

For both positions there is a three-year contract, roundtrip travel, and salary in accordance with training and experience. Apply to S. Elizabeth Ralston, Teacher Placement Secretary, Near East College Association, 548 Fifth Avenue, New York 36, New York.

State Meeting

The annual meeting of The Ohio Academy of Science is to be held at the University of Cincinnati, April 20-22.

Whack That Quack

— Report of a Classroom Project That Involved the Community —

ARLENA E. SENECA, *South Mountain High School, Phoenix, Arizona*

Introduction

The development of youth, which we call education, is not a learned thing that the teacher may pass on to the student like the multiplication tables or the six trigonometric functions. Rather, it is a process of growth brought about through realistic consideration of the problems of our environment, living through human experiences with individuals in an environment, and a recognition of the major aims and objectives realized from the process by which pupils live.

If the teacher is to make life better now and in the future for the children in his care, he cannot overlook any opportunity to help his students plan experiences that may aid them in their attempt to think critically about problems and situations in their environment.

Case Studies and Method of Procedure

J. C. came into class late one morning during the beginning of our school year. He stated his reason for being tardy. He also stated that he had been late for work that morning and expecting a tongue lashing from his boss and got it. While questioning him further, I learned that he had walked under a ladder and to him this meant "bad luck." Another student standing nearby sanctioned his belief about bad luck. In addition, J. C. believed that opening an umbrella indoors would cause one to meet with ill fortune. By this time the whole class had been alerted. Several hands were raised and students were eager to relate their experiences. I felt that this was an opportune time for students and teacher to engage in learning experiences which could be of lasting value. As the students continued to relate their experiences, we found them more interesting. One student asked me if I had ever eaten fried rats. Of course the answer was and still is "no." J. C. stated that his mother had stood him in a corner of the house and swept him downward with a broom in order that he would learn to walk. I asked him if the sweeping helped and he answered most emphatically, "It certainly did." When the enthusiasm was at its height, the teacher suggested to the students that we investigate these experiences to see how much truth we could find in them. Since units in our biology classes are arranged in order of greatest importance to students in that class, we felt free to delay the other unit of work that we had prepared for that time.

During the next week, we organized the class for our work on superstitions and home remedies. Our goals included: 1. Learning how to think critically about problems in our community. 2. Learning how to find answers to questions, the use of authoritative sources, and the spreading and dissemination of knowledge.

When we were reasonably sure about the direction in which we were going, we discussed methods of returning the information to the community. The following suggestions were given by students:

1. We could go to churches in small groups and tell the people what we have learned.

2. We could sponsor a public meeting.

3. We could send speakers to each homeroom in the school.

4. We could pass out information to mothers attending our open house.

Other suggestions were given, but these four seemed to adhere more closely to our objectives. After a period of discussion, we decided that we would prepare a pamphlet and distribute copies to each parent who attended our open house. Our planning, next, included the contents of the pamphlet, how to write the information, suggestions about collecting the information, suggestions about designing the cover, and printing the information in its final form. We browsed through several pamphlets in order to determine generally the form used. We finally decided that our pamphlet would contain the

following information: a Foreword, an Introduction, Acknowledgments, a Table of Contents, Community Remedies with the number of students practicing each remedy, Comments from Authority, and the following paragraphs: Good and Bad Home Remedies, Some Hints About Home Remedies, Information About Getting Medical Help in Our Community, and a Conclusion.

Students were given suggestions about how to approach people in the community concerning their use of home remedies and the importance attached to their bringing in accurate information. We were excited indeed because our "WHW" contact on the community was about to begin, that is, when to contact people, how to contact people, including authority, and whom to contact. All groups of people were to be contacted.

To carry out our study, we used the group method. We felt that the group method of study might give the student an opportunity to feel responsible for a job. It could also give him a sense of belonging and a chance to contribute to a wholesome endeavor. However, the whole class was organized for the purpose of collecting information. We believe that every opportunity should be taken to use subject matter to the greatest advantage in the solution of problems.

Our general plan of work was carried out in this way:

I. Classroom discussion to decide upon a name for the pamphlet
   A. The final selection was, "Whack That Quack"
II. Dividing students into groups for the purpose of writing according to their interests
   A. Writing and discussing the written paragraphs
   B. Rewriting paragraphs in the English classes
   C. Criticizing and selecting the final paragraphs. This was done by a special committee composed of an English teacher, a student, and the biology instructor. Final paragraphs were selected according to their usefulness, correctness, and uniqueness.
III. Appointing a group to work with the art department for the purpose of preparing a cover for our pamphlet
IV. Collecting information from the community
   A. Listing, on the board, remedies that had been collected from the community
   B. Discussing information, eliminating duplications and recording the final list of remedies
V. Contacting authority
   A. Consulting registered nurses, doctors, and pharmacists
   B. Engaging in research and discussing our findings in class
VI. Selecting a committee to compile our information
   A. Organizing the class to help with compilation, stapling, etc.
   B. Distributing the pamphlets

Nine of the final pages in our pamphlet look something like this:

Foreword

The units in our biology classes are developed around the things the group wants to understand and know about. The units are arranged in the order of greatest importance to the students in that class. Students and teacher plan the way of working, the materials to be used, group obligations, and due dates.

Groups in this class collected information from laymen, nurses, doctors, and pharmacists who live in our community. As a result of our study, they wrote the sections that you will read on the following pages.

We feel that a number of the findings presented here lack the advice of chemists and some form of laboratory analysis. Therefore the information compiled is not conclusive, but we hope it is a step toward better living in our community.

Introduction

In this pamphlet, we wish to bring you some information about fake ideas and practices that we have found here in our community.

After reading this pamphlet, we hope that you will be able to answer some of the questions in your mind about superstitions and the "old time" remedies.

We were indeed shocked to learn that twenty-five members of the biology classes practiced the remedy of "letting a dog lick

a sore in order to make it heal." There were two students in our class who ate fried rats to break the habit of urinating in the bed.

We hope that this little pamphlet will bring out the point that it is better to see a doctor before trying your home remedy, because after you use your remedy, it might be too late.

Remember, that superstition is a way of thinking when you have no scientific facts on which to base your conclusion.

Wilma J. Judie
Dorothy Black
Evelyn Y. Johnson
Robert Twiggs

Community Remedies

Remedy	No. of Students Practicing
1. Hog hoof tea for colds	26
2. Sardine oil for mumps	46
3. Corn cob or corn shuck tea for measles	19
4. Urine on head for sores	1
5. Smoking horse manure for headache	1
6. Drinking cow manure tea for colds	7
7. Tea from sheep fecal matter for pneumonia and whooping cough	2
8. Pull up palate with lock of hair	2
9. Soda and vinegar for indigestion	23
10. Tea made with ashes for upset stomach	1
11. Tea from boiled toads for colds	2
12. Clay mixed with vinegar placed on sprain to draw out soreness	4
13. Coffee grounds combed through hair to make it wavy	6
14. Lemon juice to bleach elbows	2
15. Let dog lick sores and they will heal	25
16. Fried rats good for kids who wet the bed	5
17. Drink juice from a poke salad vine for female cramps	2
18. Rash on tongue can be cured by the breath of one who has not seen his father	22
19. Sitting over burning horse manure will cure the piles	1
20. Snuff and tobacco good for stings	23
21. Salt and black pepper good for sore throat	11
22. Bag of warm salt placed on the head will cure fever	4
23. Mixture of sulphur and vaseline will cure fever	6
24. Onion, sugar, and turpentine placed under the bed will cure fever	1
25. Salty water for conjunctivitis	12
26. Kerosene for cuts and wounds	33
27. Boil jimson weeds and bathe sores in the hot water to heal them	2

Good and Bad Home Remedies

A home remedy might be considered good if it has direct or indirect effect with what it is intended to cure, or if it contains a chemical or group of chemicals that will affect the ailment.

Home remedies can affect certain parts of the body through the stomach, the brain, the lungs, and through the skin. Some home remedies are complete superstitions and are more harmful than helpful. Some are mere acts that do not affect the body in any way, and it is better that they do not in some cases.

Scientists have found that many home remedies are just a combination of substances combined by a quack, and while combining these substances, he was more interested in his pocket book than he was your health. Therefore, it appears to us that we play a game of chance when we depend upon the quack doctor. Our bodies are too important to be left to chance. A home remedy may be considered bad if it has not been recommended by your family doctor. Beware of "handed down" cures for there are few that can pass a scientific test.

Will Allen Martin
John Thompson
Robert Banks

Community Remedies and Comments From Authority

Collected by the Class and Compiled by Edna McClain and Chemetra Brent
The Remedy, followed by *Comments from Authority*

1. Sardine oil for mumps . . . There is nothing in sardine oil that will cure mumps. In time a person will get over the mumps without any outside effort.
2. Salty water for conjunctivitis . . . Salty water is not good for conjunctivitis because it will burn the

eye and make the eye red.

3. Let a dog lick your sore and it will heal . . . This is not true. Instead of healing, germs from the dog will enter your sore and cause infection.
4. Soda and vinegar will cure indigestion . . . Soda is too strong for many people and may hurt the lining of the stomach.
5. Fried rats will keep children from urinating in the bed . . . Fried rats are not good for anyone. Rats may carry disease.
6. Drink cow manure tea for colds . . . Cow manure tea is not good for colds because it contains bacteria and may cause infection.
7. Rash on tongue can be cured by the breath of one who has not seen his father . . . This is not true. Germs may be transmitted from the mouth of the older person to the child.
8. Urine on the head will cure sores . . . No. Urine is waste matter from the kidneys and contains ammonia which does not cure sores.
9. Clay mixed with vinegar and placed on a sprain will draw out the soreness . . . Clay and vinegar will draw out soreness. It depends upon what part of the country you get the clay. Vinegar contains acetic acid and glycerin which will "draw out soreness" under some conditions.
10. Poke salad vine good for female disorders . . . Female illness can only be cured by scientific medication. There is no evidence to support this idea.
11. Coffee grounds combed through the hair will make it curly . . . There is no evidence to support this idea. Permanent curly hair is inherited.
12. Tobacco and snuff good for stings . . . Snuff is a powdery form of tobacco. Tobacco contains a harmful drug called nicotine. Nicotine aids in sterilizing the sting.

Information About Getting Medical Help in Our Community

When we need medical help in our community and are unable to pay for medical treatment, we may go to the free clinic. When some mother becomes pregnant and does not have enough money to pay her hospital bill, she may go to the Clinic and the Clinic will be glad to help her.

1. Visit your Health Clinic if you are not able to pay for private treatment.
2. See your private doctor.
3. Go to the Maricopa County Clinic and you can find out what you should do next.

Clara Scott
Barbara Mosely
Vernel Wilson

In Conclusion

We of the 4A Biology Class, after consulting physicians, pharmacists, nurses, and other authorities, have presented some of the do's and don'ts about community remedies. Our hopes are that this will help combat ignorance in the use of home remedies.

We do not expect to achieve our goal in one day, but we hope that we can do away with the use of community remedies in the near future, so that in the generations to come, community remedies will be a thing of which children read about in history books.

Warren Bass
Fred Warren
Carl Chambers

Bacteriology Manual

For use in high school teacher institutes and for reference purposes for those who are concerned with problems of microbiology in introductory biology courses, Dr. Carl E. Georgi and Richard Y. Morita have developed a mimeographed manual, "Instructor's Manual of Bacteriological Exercises for the High School Biology Class." This has been used successfully in the Summer Science Institutes at the University of Nebraska, Lincoln, and a copy may be obtained without charge by those interested by writing to Dr. Georgi. The manual includes exercises designed to demonstrate activities of microorganisms in "cycles" in nature, and most exercises employ mixed cultures rather than pure cultures.

The Application of Inductive Procedures To Selected Topics For High School Biology

F. L. NICOLAI, *University of Nebraska, Lincoln*

The time has long since passed when the high school biology teacher's primary role was merely to impart to a group of students information which they were to recall, more or less in detail, at a later date. Today, the successful teacher knows that the introduction of diverse procedures is necessary and desirable, and that such practice will stimulate student interest, enrich the program, and result in better learning of the material presented. One procedure which has been neglected, for the most part, in science teaching in general, and in the teaching of biology in particular, is that employing the inductive process. Traditionally, science teaching often seems to have been based upon the rote learning of factual information. This process —one of the simplest forms of learning— seems inappropriate as the *principal* learning procedure to be employed in science courses.

Basically, the inductive process is reasoning from particulars to generalizations. Students all too frequently are not given opportunity for making observations and from them arriving at generalizations. The chief value of the inductive procedure is not that students arrive at "correct" generalizations consistently, but that they often have the opportunity to employ this type of reasoning under competent direction. The high school classroom situation, by its very nature, provides little chance for the student to make signal discoveries; however, it can provide ample opportunity for the student to discover ideas new to *him!* As far as the student is concerned then this is real discovery.

Observation and experimentation are the fundamentals of science, and should be carried out at the secondary school level. From observations and experimentation the student should be able to make "calculated guesses" or tentative hypotheses which may be compared later with information found in textbooks or other reference material. But the student must be given frequent opportunity to practice this fundamental reasoning process, if it is to develop as a permanent part of his thought patterns.

Two general topics commonly considered in high school biology have been selected to illustrate the use of inductive methods. Following is a general outline of the procedures:

1. Teacher makes provision for student observations of phenomena.
2. Teacher and/or students tabulate questions arising from the observations.
3. Teacher and/or students tabulate known facts regarding the observations.
4. Teacher formulates "leading" questions regarding the phenomena observed.
5. Students establish tentative conclusions.
6. Students compare their tentative conclusions with those found in reference materials and from additional experimental research.
7. Students determine what basic principles or generalizations, if any, can be established upon the basis of the observations and research.

Classification-Taxonomy

The classification and taxonomy of organisms as such should not, perhaps, be a topic for major consideration in high school biology courses as they are taught in many schools at the present time. However, it does seem appropriate and necessary that high school students become aware of relationships between organisms and groups of organisms and of man's systematic classification of his knowledge about them. If this viewpoint is acceptable, then some opportunity should be provided for students to acquaint themselves with this area of scientific endeavor.

It would seem desirable to consider the topic of classification as an introductory topic in high school biology, and in many

places this can be accomplished satisfactorily. Other situations, because of their geographic location, may require that the topic be covered at different times throughout the school year. In any event, there are certain procedures which may be followed.

Ideally, actual organisms, both plant and animal, should be used for this study. Certainly, the greatest variety of living organisms that is possible to assemble should be made available. These are then supplemented with models, preserved specimens, photographs, and films. It is essential, though, that representative organisms from the major groups in the system of classification be available to the students in some form.

The proposed procedure to be used for consideration of this topic is designed to give the students some knowledge and insight into the system of classification for plants and animals. The rote learning of this material at the high school level, for the most part, is of little value from the standpoint of real understanding and retention of the important concepts. Therefore, it seems that students should have an opportunity to observe a wide variety of organisms for the purpose of grouping them on the basis of the observations they have made.

To initiate this activity, the teacher asks the students to bring to class a variety of living specimens which they are able to find in their environment. There should be several of each kind, if possible, and the class should be divided into groups of four or five students for the purpose of careful observation of the material. Each study group is asked to arrange these specimens on the basis of characteristics observed. The study groups should work independently. After the students have arranged the organisms, the results from each student group are tabulated on the chalkboard for comparison. It may be found that some of the "classifications" will have been made on the basis of color; others will have been based upon structure, form, size, and behavior. From the tabulations, the teacher may stimulate discussion as to the validity of the classifications which have been made. It might be suggested that some of the plants and animals be dissected to determine if there are any internal characteristics which may be useful in classifying certain organisms. Further questions may be asked by the teacher, if they have not already been posed by the students, regarding the form and structure of specific organs, number of appendages, and the positional relationships of organs.

Not until these avenues of approach have been exhausted and the observations completed should the class turn to textbooks or other reference materials. The tentative conclusions arrived at and agreed upon by the majority of the class are to be compared with those found in the reference material.

Following this activity, the teacher might choose to discuss with the class the terminology used in classification systems and the origin of some of the terms. These terms should then be used by teacher and students when appropriate, but rote memorization of the terms should be discouraged.

Some of the generalizations and concepts desired in a study of this kind are:

1. Certain natural relationships exist between groups of living organisms.
2. Classification of organisms is simply a device contrived by man for organizing his knowledge about them.
3. Classification is based upon different observable characteristics; e. g., floral morphology, anatomy, and leaf structure.
4. Certain organisms yet remain to be classified within the framework of present systems.

This study may be modified in several ways, but the basic procedure should prevail. For example, a teacher may wish to consider the animal and plant kingdoms separately, or organisms might be studied at different times depending upon their availability in the local environment. In any event, the students should be given every opportunity to make their own observations and to draw from them their own conclusions. The teacher should serve as a leader who initiates and directs the observations but who resists the temptation to become authoritarian.

Mitotic Cell Division

Mitotic cell division can be introduced at the tenth grade level in high school biology through the use of procedures that will enable the student to formulate, as a result of observations, certain appropriate generalizations.

The topic is introduced, preceding any

specific reading assignment on the subject, by showing carefully selected slides that illustrate many stages of mitotic cell division in several tissues or by the use of an appropriate film as hereinafter described. Commonly used slides can also be employed for this procedure. Among the most common tissues used are crayfish testis, *Crepis* root tips, *Ascaris* sections, sections of whitefish embryos, and onion root tips.

Following the teacher's introductory remarks, the selected slides are shown in random sequence by means of a microprojector, or they may be microscopically examined by individual students if facilities permit. Students should make rough sketches of the series of chromosome configurations they observe. Some students can be encouraged to make pipe-cleaner models of the chromosome configurations. After the slides have been carefully observed, several viewings will be necessary, and sketches or models made, pupils should be asked to arrange the configurations in what they believe to be an orderly and logical sequence. The arbitrary terminology for mitotic stages; viz., interphase, prophase, metaphase, anaphase, and telophase need not be mentioned at this point.

As questions arise they are carefully tabulated to insure that each of them will receive adequate attention and consideration by the class. When all the facts have been marshalled and previous knowledge reviewed, the class will be ready to make some tentative guesses as to what happens when the nucleus undergoes some of the changes that have been observed. Their conclusions can then be compared with those found in the textbook and other reference sources.

Certain films may be effectively employed within the basic framework of the procedure used with slides. Any of a number of good 16 mm. sound films which shows mitotic cell division by means of time-lapse photography and animation will serve this purpose well. The film, or the appropriate part of it, is first shown with the audio portion turned off. This technique provides the students with opportunity to interpret for themselves the phenomena they have seen. Their interpretations may be evaluated later by subsequent showing of the film using both the audio and visual portions.

With either approach, i. e., the slides or the film, the questions which arise may necessitate showing the materials a number of times. Several class periods may be needed merely for observation and formulation of questions. This will be determined by the knowledge possessed by the students, the background of the teacher, the extent to which the teacher wants the class to pursue the topic, and the overall consideration of the time factor.

Some generalizations to which these activities can contribute understanding are:

1. The result of mitosis is an increase in the number of cells.
2. The process is similar in diverse tissues and organisms.
3. Somatic cells normally have equal numbers of chromosomes in a given organism.
4. Tissue growth takes place when cells increase in number.

Questions arising from this study of cell division may lead, quite naturally, into the study of heredity which can be treated in a similar manner.

The success of this procedure depends largely upon the questions asked of the students. Questions should be appropriate and timely. One basic purpose of the questions should be to create problems which the students will *want* to solve. Instead of questions of the type: "What is the name of ....?" "What is the function of........?" there will have to be more questions of the following form: "What do you think ....?" "Is it reasonable to believe that ....?" "What reason do we have for believing that ....?" and "How can we explain ....?"

NSF Publication

The National Science Foundation has issued *Reviews of Data on Research & Development*, No. 24, "Funds for Performance of Research and Development in American Industry, 1959."

Copies of this bulletin may be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., for 10 cents.

Suggestions for Teaching the Scientific Method*

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Introduction

Teachers of science agree that students should learn the logic of science regardless of the discipline under which they may study later. In a recent survey, the Dean of the Harvard Graduate School got from some of his graduate doctors a very common complaint, "especially in Economics, Government and Social Relations, that (their predoctoral) . . . training (had been) weak in methods of research, in statistics and in the *Logic of Science*" (capitals and italics mine).

Some Paradoxes of Our Science Instruction

One of the common errors of American education is the view that science can be properly taught without observation and without experiments. Though I know of Genetics courses taught without *Drosophila* or corn, I believe that science is best taught when a laboratory supplements the lecture room, and when a manual accompanies the textbook. But laboratory manuals do not, as a rule, have exercises to demonstrate the methods scientists use. Again, most textbooks discuss the scientific method, some but lightly, and others, paradoxically enough, though admitting that a scientific attitude is one of the benefits of science education, treat methodology as if it were a trade secret or a fraternity handshake. I have found over the years that science teachers expect their students to pick up scientific methods by osmosis. But since the "won't-learns," the "don't-learns," and the "can't-learns"—a large proportion of our present students—do not recall even those ideas we teach by drill, they certainly do not catch the idea of scientific methodology by inference or by suspicion. That, however, is how we teach.

It is well known that specialists scorn the idea of special techniques in science instruction. Hidden behind microscopes, or atom-smashers, or lost in their test tube forests, they believe that if a teacher "knows his material" well enough, or if he has written much, or has made a reputation for original research, he is *ipso facto* a good science teacher. These are false assumptions. But they have guided our college teaching for generations. Fortunately, the number who still hold these views is rapidly decreasing. In fact, scientists of high repute as teachers, lecturers, and researchers are now assisting in the preparation of science teaching programs, and our science teaching societies are accordingly growing at an encouraging rate.

A talented student with a good background may succeed in spite of poor teaching, but the less gifted, the "science-major," and the nonscience student, who is touched by only one or two courses in natural science, must have good teaching. These need to know the techniques of the scientific methods. Many students come to our colleges poor in training, in background, or in native ability. Some are deficient in all three. In the next decades our colleges will be crowded with pupils of ability, background, and preparation below our present crop; hence, we must now, I believe, devise for our science courses laboratory exercises which deliberately demonstrate scientific methods. As the students work at experiments, they should get a clear idea of what the scientific attitude is. We cannot leave it to chance that these important ideas will somehow filter into their minds. All college students, regardless of their vocational interests, should learn to recognize these intellectual procedures; otherwise, they will be handicapped later as they become adults in a free democracy. "Since scientific investigations provide . . . examples . . . of effective(ly) handling problems, a greater knowledge . . . of scientific methods ought to be imparted by our schools and colleges." (Conant)

I therefore repeat my conviction that in every beginning course in science, we should lay out one or two explicit exercises to demonstrate the scientific methods. These should be carefully planned and referred to frequently during the course, as opportunities

*Presented at the annual meeting of NABT with the AAAS in Washington, December, 1958. Dr. Crooks died a few months after this paper was presented.

arise. The repeated references should show our students that scientific methods are valuable procedures and can help in tackling the problems of life, and that the scientific attitude is really a state of mind, with which one faces the world—really a WAY OF LIFE.

A recent editorial in *Science* suggests that "the main emphasis in education must (now) be placed on methods of obtaining knowledge," rather than on the hoarding of stores of static information. This is precisely the point of my contribution.

The Ten Ingredients of Scientific Methods

Though we may differ about minor points and the order of topics in the scientific solutions of problems, though I am taking sands to the Sahara, when I review the steps before an audience of scientists and science teachers, I believe the following explanation is in order as it may offer the ideas our students need. I suggest ten ingredients.

1. *Curiosity*. There must be a desire to find out something new about something old or familiar and a wish to improve the *status quo*. Sometimes, a latent, unrecognized curiosity may be aroused by a casual observation. During the last century, for example, two German scientists, doing vivisection experiments on dogs, noticed that ants swarmed into cages of the experimental animals. But not into those of controls. Curiosity about this observation led to the discovery of sugar in the urine of dogs from which the pancreas had been experimentally removed and supplied knowledge which later helped other curious men to the conquest of diabetes. Examples such as these will show students that if they have not the interest to ask questions, they lack the first requisite of a scientist and of a good citizen. Curiosity separates the sheep from the goats.

2. *Is there a problem?* Having curiosity, the scientist must identify the problem and state it clearly. In the illustration just given the problem was clear: why did ants crawl into some cages and not into others? Problems are nearly always questions—What? How? When? Where? Why?

3. *Get the Evidence*. To answer the problem question, the worker collects evidence by observation, reading, experimentation, reflective thinking, speculation, or even by a "flash of inspiration." The gathering of ideas is important in a scientific procedure.*

4. *Attributes Needed*. During the entire procedure, but especially in the collection of ideas, the scientist should have certain personal attributes. Among these are *integrity*, *unbiased impartiality*, *broadmindedness* (three components of *honesty*), *accuracy*, *ingenuity*, *persistence*, and the alertness of mind commonly called *intelligence*. He must be keen enough to discard the irrelevant and eschew the spurious and yet be able to relate ideas which seem unrelated. The gift of "inspiration" is most important too.

Though these abilities are native to some persons, they can be trained into others. One needs not, therefore, be a "born genius" to be scientific. As a matter of fact, though, most of our early scientists were gifted amateurs, and most of today's topflight workers are blessed with these traits. Many of us engaged in scientific work or in science teaching have acquired these attributes by persistence, special training, or individual effort.

5. *Weigh All the Evidence*. The ideas and data collected under operation 3 must be studied and analyzed; in some cases they must "ripen," sometimes for years. Often too, data seem worthless or without significance until other discoveries or speculations bring new light to them.

6. *Make the "Educated Guess" (Hypothesis)*. From a study of collected data and related ideas, the investigator makes a generalization. This is the hypothesis and is reached by inductive reasoning—from many ideas to one thought. Unfortunately, many persons have the idea that the hypothesis is the first step in scientific methods. That is wrong. Some also believe and teach that inductive reasoning IS THE scientific method. That idea too is wrong, for it is only one of the many ingredients.

*There is evidence that the human mind is impressed with ideas in the subconscious. Thus, perhaps, a concerned, inquiring mind may collect, assort, and analyze items, some even apparently unrelated—and all without the person's knowing it—and then come up with a result, which rises to the surface, so to speak, and flashed into the consciousness. The brilliant intuitive guesses of Edison and Einstein, the concept of the benzene ring by Kekule, "hunches" of the common citizen, and the intuition of wives seem to be examples of this subconscious phenomenon. But I know little about it.

7. *Challenge the Hypothesis.* Since a good hypothesis should fit varying conditions and the known facts, it should satisfy data obtained by others. It should also contain predictions of later observations. If new facts do not support the hypothesis, the new facts should not be repressed, hidden, or sacrificed. The hypothesis must rather be brought into agreement. A good hypothesis, like a man of good character, must be able to stand up under criticism. The challenge may require a discussion—either verbal or mental—to eliminate doubts. However, the new ideas must be examined for a decision as to whether they should be accepted or rejected. If accepted, the new data must be used to check the validity of the hypothesis.

If experimental data are used, the scientist applies Aristotle's *Principle of the Single Variable*, or he uses trial-and-error or cut-and-try methods. I prefer the term trial-and-success. He may also do *control experiments.* Here the student should learn the difference between the manipulation of apparatus to see what happens and the purposeful experimentation done according to a scheme. Both are of value: the first, to get data and knowledge, even if its import is not recognized for some time; the second, to get specific answers. This checking of the hypothesis is a severe test of patience and ability. Edison spoke of it as "ten per cent inspiration and ninety per cent perspiration."

8. *Get a Conclusion* (Modify the hypothesis). As a result of the critical challenging, the hypothesis is modified; it is made broad enough to fit all acceptable data, yet limited enough to meet special exceptions. This modification is the Conclusion or Theory.*

9. *Suspended Judgment.* The investigator must stick to his conclusion until it is proved wrong, but he must keep an open mind and be ready to accept new evidence or speculations if sufficiently convincing. He is therefore ready to adjust his own views if they are untenable. This is the crux of the scientific attitude: an abiding faith in some view or opinion allied to a healthy skepticism, a questioning challenging doubt of new ideas, but a mind definitely open to new ideas. This sounds conflicting, but it is not. The true scientist or the citizen with a scientific attitude is no bigoted stand-patter, but he is no wishy-washy turn-coat either; he does not go chasing after strange idols, just because they are new, nor does he condemn another idea just because it is old. He realizes that truth is not simple, that knowledge is forever growing, and that opinions thought correct today in the light of present knowledge may be thought incorrect tomorrow because of new discoveries or the projection of new ideas.

10. *Deductive Reasoning.* This thought is often omitted in discussions of scientific procedures. A conclusion induced from many items may be used to predict a truth for other cases. It is by deduction that the surgeon confidently opens your abdomen to remove your appendix. Yours should be in the place anatomists have found them in cadavers, and other surgeons have found them in other patients.

Huxley, in his famous lecture to English workingmen, said that if one had bitten many small, hard, green apples and found them all sour, he would reach a justifiable conclusion by inductive reason. If the same person then picked up a small, hard, green apple, he would naturally by deductive reason decide that it must too be sour. In a court of law, the evidence is built up by induction and from hypotheses planted in the minds of judge or jury; the lawyer drives home his case by deduction. If induction is the head, deduction is the tail of the coin of our scientific procedures. They are inseparable.

The Suggestions

Regardless of the methods used, I believe that science teachers should keep these ten guides—or whatever others they may select—in the minds of the students at all times. I present here a few suggestions which students may follow without equipment or expensive apparatus. They are written out as I present them to my classes in biology.

I. *Making Scientific Observations.*

A. *Procedure.* These laboratory directions

*At this point, I offer a personal criticism of much of the current published scientific literature. Investigators too often fail to draw any conclusions from their work. They present masses of data, pages of review of the literature, but offer no concluding opinion as to what they believe they have discovered or the state of their thinking on the problem.

should help you learn about scientific procedures. Follow the instructions carefully.

Stretch out your left hand, fingers together, palms up and with the long axis of the third finger, hand and forearm in a straight line. Note the relative lengths of your fingers. Number them from thumb, 1, to little finger, 5.

If finger 2 is taller than finger 4, you are in Group A;

If finger 2 is shorter than finger 4, you are in Group B;

If finger 2 is about as tall as 4, you are in Group C;

If finger 3 (middle finger) is shorter than 2 or 4, you are in D.

Determine into which group your left hand puts you.

Study the left hands of about 20 person (both sexes) and note into which groups they fall. Record name, sex and group and summarize into a table. Picked at random is a table recently turned in by one of my students:

Group	Number of females	Number of males	Total
A	6	5	11
B	10	11	21
C	4	2	6
D	0	2	2
	20	20	40

Instructor's Request (Your Assignments):

1. What you have now done falls under the first three headings given above. Granting that you were curious (item 1), write out the problem as you now understand it (item 2). You may use a question, if you wish.

2. When you inspected other people's hands, you were carrying out Operation 3. Did you respect the suggestions noted under item 4 above? Did you need any or all of these attributes? Did you have some difficulty with regard to any? Explain this briefly, but truthfully.

3. Study the table prepared, noting relationships and numbers. Then jot down some generalizations or ideas suggested by the data. Did you pay attention to the sexes? Does this add more to your ideas? (Operation 5)

4. You are now ready for Operation 6. Write out some hypotheses which you can induce from your observations.

5. To verify your views and to check their accuracy, collect data from several classmates and make up a master table of say 100 persons. Did any of your classmates by error study the right hands? Whether they did or not, do you think it would be wise to study right hands also? Give reasons.

B. *Procedure* (continued). Study your right hand. Into which group does the right hand put you?

Since you have two hands, you should now belong to two groups. Name your left hand first, then your right hand, so that your group will have two letters. *AA* means both left and right hands are in group A; *AB* means left hand is A and right hand is group B, and so forth.

Make a master list of the data collected by the students in your class. Note name, sex and group (two letters). Then summarize this into a table. For illustration, I give here some recent results from my classes.

Group	Number of females	Number of males	Total
AA	156	241	397
AB	353	232	585
AC	*	*	
AD	*	*	
BA	87	24	111
BB	1551	1455	3006
BC	88	96	184
BD	*	*	
CA	*	*	
CB	51	98	149
CC	334	212	546
CD	*	*	
			4978

INSTRUCTOR'S REQUESTS: 1. Does this last master table seem better than the table made for the left hands of 20 students? Can you make other generalizations? Compare them with your earliest hypotheses. Which seem more accurate? Why? Write out these new hypotheses.

2. Suppose a student from another class shows you a master table and generalizations different from yours, what would you do? What SHOULD you do? This is Operation 9.

3. For Operation 10, consider your data, and your hypotheses, and your theory. Would these help you to make a true statement about a class of students from the Far North? A class of German law school students? Dis-

*These and groups DA, DB, DC, and DD less than 50 each.

cuss these deductions in writing and suggest a conclusion you would draw from this entire exercise. This conclusion is your "discovery."

II. *How to Write Up A Scientific Report.**

Scientific observations and the hypotheses and theories developed from them deserve good recording. Scientists, rather conservative in this procedure, follow a time-honored pattern. Follow the suggestions below and write a report of your observations and conclusions; use these headings:

1. *Purpose*. Define the problem. That means write out in a short sentence, or a question, the purpose of the observations you made.

2. *Procedure* (Materials and Methods). Describe briefly but accurately what you did and what apparatus or equipment you used. Neat sketches are helpful, for often a good picture, no matter how simple, is worth a thousand words. Do not give any data here. This part is necessary as it enables another person to check your work exactly.

3. *Observations.* Here report your results. Make tables and if you have satisfactory data, graphs. Sometimes your primary data may be used to develop secondary information, which may give further light on the problem.

4. *Discussion.* State the views you have gained from a study and analysis or synthesis of your data. Write out the line of argument you followed in getting your generalizations and the reasons you have for accepting or discarding data from other classmates. If you reword, modify, or change your original hypothesis, explain why.

5. *Conclusions.* From your observations, restudy, and discussion, you should reach certain conclusions. Write these out clearly and briefly. These views are your "discovery."

6. *Bibliography*. A scientist working on a problem may not be able to find other scientists working on the same problem and from whom he may get data as you did from your classmates. But he gets help by *consulting the literature*—that is, finding and reading critically articles, reports and books. Some of this literature may be hundreds of years old; others as recent as yesterday. To show your familiarity with the subject, and to support your views, in the report and in the discussion, you should quote references to the ideas of others and state where these may be found. Styles differ, but here are some acceptable forms, the first being a book, the second an article:

Adams, Eve. 1976. "Fingers Will Tell." New York.

Hoover, F. B. I. 1963. Journal of Criminology. XXV: 16-34.

INSTRUCTOR'S REQUEST: Follow these directions and write up a report of the exercise you did on the observation of human fingers.

Here again, I regret bringing these very obvious things to your expert attention. But as I feel these have not been sufficiently stressed as these are the exercises I give to my beginning pupils; I report them in full as suggestions.

III. *Making Observations and Doing Experiments*

After students have gone through exercises similar to the two above, they are then ready for work on their own in the laboratory. I have chosen only a few exercises, and to save time I omit the Instructor's Requests which are essential in the laboratory work.

A. With the microscope—to find out about magnification and the inversion of the image. This exercise does more than teach the conventional use of the microscope; it introduces the student to experimentation.

B. To find out the relation of muscular activity and the pulse rate. A table submitted recently by one of my students looked like this:

		Average pulse rate per minute				
Subject	Sex	Lying down	Sitting	Standing	After Walking	After Running
A.J.	F	76	80	88	94	118
B.S.	M	70	74	82	88	100

C. What factors make germination possible? Parts of this exercise are:

1. *Directions*. Prepare several small glass jars for germination of small seeds. Place the jars in the following places—a. in a refrigerator; inspect at least once per day and keep the can moist; B. under a bright light such as a 100-watt desk lamp; c. in a dark, warm cabinet, but do not wet the sand at the beginning of the experiment, and do not moisten it; inspect the other jars daily and keep the sand moist; d. in an incubator

*This exercise should not be attempted until all the instructor's requests above have been satisfied.

at 37.5°C., place two jars in the incubator, but moisten only one of them.

2. Prepare two other small germination jars. Place each in a petri dish so that the dishes float in water in a large glass dish. Also place a candle in each of two other small petri dishes so they will float. Light one candle and immediately cover both sets of dishes with large bell jars, two petri dishes under each bell jar. After the lit candle has gone out, observe what happens to the water under this jar. Compare with the water level under the jar with the unlit cadle. Explain.

Cover the two set-ups, so that no light gets under. Leave in a warm room and compare the germination in the oxygen-free bell jar with that in the jar containing oxygen.

INSTRUCTOR'S REQUESTS: 1. Review the 10 "ingredients" suggested above.

2. Study the exercises and identify those procedures which illustrate the *principle of the single variable*. Identify and name the variables. Which of the experimental jars are *controls*? Explain. Why are these controls necessary and valuable?

3. Using the method learned previously, write a report of these experiments, using sketches where needed. Identify the steps in scientific procedures in these experiments on germination.

4. What conclusions do you draw from the data collected and from an analysis of your observations?

We have all used these ideas for they are not original. But I believe the purposeful approach is different for these suggestions are concerned more with procedures and mental attitudes than with subject matter and teachers.

In the light of persistent efforts to "dilute" the subject matter of science courses and the violent and typically American reactions which followed the launching of the Soviet Sputniks, I feel obliged to state categorically that I do not believe in "watering down" our science nor in lowering standards of quality. However, I do feel that the addition of minutiae and inclusion of new topics without elimination of some of the old serve more to weight down our courses with quantity without necessarily achieving the quality for which we all strive.

I believe that regardless of his discipline—whether the student in my science class is preparing for a career in teaching, industry, physical sciences, biological sciences; whether he is going into one of the professions or the newer technological fields, or taking science for "general education,"—a student should early in his science studies be taught the methods scientists use before he takes up the subject matter of what the scientists have discovered and postulated.

The student should thus learn in the beginning that science is forever on the march, and that a course in science should do more for his attitude and his way of life than for his store of knowledge. By acquiring the correct mental posture, he will more easily add to his knowledge later by his own efforts.

Teachers of science should therefore recognize that they have at least FOUR functions. Named in order of importance these functions are:

1. To help students learn HOW TO DISCOVER;
2. To develop and encourage in students the scientific attitude;
3. To bring to students the facts, theories and principles of the sciences (subject matter);
4. To keep abreast of the forward march of knowledge.

In addition to these four, I believe a fifth should be added; that is, an obligation to do some kind of investigation, no matter how simple and no matter how specialized.

These, ladies and gentlemen, are some of my suggestions. I am sure you have thought of these things, even worried about them. Some of you have voiced opinions on these problems. Because you and I, as teachers of the sciences, love the work we do, and wish our efforts to be more successful than ever, I hope that ours will not be voices crying in the wilderness.

Coming Issues of ABT

The April issue will be devoted to articles on "Conservation Teaching." The May issue will cover "Laboratory and Classroom Teaching Suggestions."

The Scientific Method—Another Look*

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"The Scientific Method," as most textbooks phrase it, is usually a brief listing of steps tucked insignificantly in the corner of a science book.

Irrespective of sequence, observation, problem defining, hypothesis postulation, experimentation, and theory are the steps that are listed in most texts. Often "The Scientific Method" is not even mentioned. Where space is devoted, this topic is rarely discussed in the light of emerging practices in research laboratories, modern applications to the social science field, and in present-day teaching situations.

Flexibility in Sequence

Textbooks vary as to the wording of the steps in this scientific procedure. Such ambiguity may not help the public school teacher, who needs probably less confusing terminology and more understanding.

One text may list *Collection of Fact* as the first step; another list may begin with *Observation*. Which text is correct? The order is unimportant. Rather than become perplexed as to which is the first step, one might find it beneficial to realize that in well-equipped scientific laboratories, personnel is within arm's reach of research journals and reprints. While one observes, facts are collected. When a person collects facts, it is not uncommon for that person to record valuable observations.

Around the clock, scientists make *observations* by merely devoting time and effort to searching volumes and volumes of scientific literature both foreign and native for background data. German, Russian, French, Japanese, Italian, Swedish, and Spanish are some of the languages in which translation service is available for research laboratories at The National Institutes of Health, Bethesda, Maryland. Can't you visualize research scientists scrambling for the literature to verify an observation, or to search for clues as to the why of such an observation and how it may be interpreted? Easily, collection of fact and observation may be combined as a single phase of "The Scientific Method."

There is flexibility in "The Method of Science." The steps are not necessarily followed to completion in research laboratories. During the experimental stage, a profitable approach to the problem may be evident. The original problem may then be approached differently or replaced by another. Outstanding work may terminate in the experimental stage for numerous reasons. Lack of funds, lack of equipment, lack of suitable assistants, lack of scientific progress in closely related fields, or even death of the researcher may prematurely conclude a scientist's labor. Textbook steps may never be followed to completion in such instances. Sir Alexander Fleming, the British scientist who began work with penicillin, spoke at Georgetown University in Washington, D.C. in 1954. Sir Alexander informed the gathering that facilities were unavailable for him to carry on further experimentation with penicillin in 1928. He, nevertheless, let it be known around medical circles what he found.(1) Credit is given Fleming for the discovery of penicillin. In 1940 researchers continued with Sir Alexander's initial work—this time after a twelve year delay facilities were available.

The Layman's Concern

The thorough science teacher must develop in his students an awareness that billions of dollars are poured into the research phase of the scientific method. This idea should be meaningful. Taxpayers' dollars form the backbone of governmental research funds. Taxpayers' funds contribute to experimentation dealing with cancer, heart, multiple sclerosis, and muscle dystrophy. Private agencies, endowments, and charitable organizations contribute toward research. Governmental programs of grants and contracts assure free, uncommitteed *research* and *experimentation* in colleges and universities. Unfortunately, Department of Defense funds for experimentation are becoming a political

*From a series of lectures to the Science Club of the school by the author during September, 1960.

issue—even though this experimentation is in the national interest. One reason for the high cost of experimentation may well be the cost of modern instruments. Man today observes more and more through the medium of high cost machines.

Instrumentation

Precision machines are quite indispensable in many areas of experimentation. Instrumentation-trained personnel are needed for proper manipulation. Universities offer graduate level courses in laboratory instrumentation. Foremost in importance in biological research is the electron microscope. By using a beam of electrons and magnetic fields in place of light and lenses, a scientist may obtain magnifications up to 100,000 times.

Observation has been made accurate and objective by precision instruments such as the spectrophotometer, turbidimeter, numerous graphic recorders, pattern tracing instruments such as the oscilloscope and other automatic registering machines. A spectrophotometer is an apparatus for measuring the quantity of coloring matter in solution by the quantity of light absorbed. Cloudiness is measured with a turbidimeter. Undirectional or alternating form of an electric current wave is observed with an oscilloscope. Closed circuit television observation is unique in that an experimental subject's environment is not disturbed by the observer. Microscopes are specially constructed for solution of difficult experimental problems. Optical companies send representatives to research laboratories and draw plans for any special microscope that may be needed to complete an experiment. Now *observation* can be extremely reliable and accurate. Instrument speed and sensitivity reduce human error as well as enabling the researcher to complete his experimentation months, even years earlier.

By mail one may request brochures describing pictorially a complete line of precision instruments. Manufacturing firms will eagerly familiarize anyone with their parade of scientific instruments. Advertisements in any science magazine or journal list such firms. Descriptive literature accompanying an automatic recording chromatograph received in a government laboratory read, "With this instrument a typical analysis takes only half a day of the operator's time. Five to ten times as many operator hours would be required for analysis by older biological assay or manual techniques. Compared with earlier analytical methods, operation of this analyzer is simplicity itself." Color perception depending upon varying velocities of absorption is measured on a chromatograph. A laboratory may be engaged exclusively in the observation stage of the scientific method. This laboratory may depend heavily upon trained operators as well as accurately calibrated adjusted "observation" machines.

The Glamour Phase

Through outstanding achievement in *observation* and *experimentation*, scientists have become famous. As an example, Dr. Gilbert Dalldorf during the course of five years tracked down an unusual virus—a very mild form of polio virus. From patients in the Hudson River town of Coxsackie, population 2,800, Dr. Dalldorf isolated a hitherto unknown virus—the Coxsackie virus. Instead of naming the virus after himself, he honored the town.(2) Usually the names of scientists are intimately associated with their contribution. Merely glancing through a high school science text should convince the reader of the fact that common names precede laws, theories, techniques, equipment, and particles of matter (Van Allen's Radiation Belt). Personal names are even associated with the location of ducts, muscle openings, nerve paths, and blood vessels in one's body. Just a few such common names familiar to one's doctor and associated with the human body are:

Tomes' fibers—John Tomes, English dentist, (1836-1895) observed dentinal canal processes.

Ranvier's node—Louis Ranvier, French pathologist, (1835-1922) observed constrictions on medullated (sheathed) nerves.

Scarpa's triangle—Antonia Scarpa, Italian anatomist, (1747-1832) observed a triangle formed by two muscles and a ligament.

These common names of medical men, early anatomists and researchers—all keen observers are intimately associated with structures in the human body. Medical students

"digging" through *Gray's Anatomy* associate these men with their contributions. This list is long and impressive.

Significance of the "Shrinking World"

Modern means of communication and transportation make it possible for scientific teams to complete the steps of the scientific method within the productive years of each researcher. The probability is great that a new idea or development in science can be expedited by means of modern communication. New ideas are proportional to the number of receptive scientific ears and to the adequacy of facilities and funds for their advancement. Exchange of scientific information is vital for maximum progress and elimination of wasted effort. What is done in one laboratory today may depend on results obtained in another. Research conducted in a different part of the world only days prior may unsnarl "stalled" progress elsewhere—thanks to modern communications. Not unusual today is the assigning of a research problem with its accumulated observational and experimentation data to another team of scientists in a laboratory thousands of miles away. All steps are not completed by the original team. Rapid communication between the two teams may be vital. Jet travel makes it possible for a research scientist to visit peers in England, discuss approaches to his problem, have lunch, and return to work in his own DuPont, Delaware laboratory that very evening.

Experimentation

Now it is my intention to convey the following ideas concerning the scientific method:

1. Nobel prize awards in science may quite adequately reveal ideas concerning the scientific method which you may wish to convey to your class. Background information as to the who, what, why, when, and how of scientific achievement might reveal ideas mentioned in this paper.

2. Disappointments and failure, during the experimental phase, is a common occurrence. What is important is a proper evaluation and continued, repeated efforts.

3. Since the scientific method is an intellectual approach or a mental guide, its use is not limited to one field of study.

4. Proper use of a control in the experimental step when applicable is a common practice in research laboratories and will convey a "true picture" when it is transferred to the classroom by the informed teacher.

From the fortune left by the late Alfred Nobel, inventor of dynamite, five annual Nobel prizes are awarded in the fields of medicine, physics, chemistry, literature, and peace work. Winners in medicine receive $43,627. Here is an international award for outstanding application of the scientific method in an area of the researcher's choice. It is not unusual for the recipient to be honored in the late experimental stage. To experience repeated failure initially seems to be the laboratory pattern for these noted winners.

Failure in *experimentation* may be more significant than success. New lines of thought may be opened. Proper interpretation and observation after failure may subsequently lead to fame. The school teacher could gain respect in the eyes of the pupil if a failure were thought of as a natural occurrence. This is realism. Mistakes occur in prominent science laboratories. Errors in space experimentation occasionally are mentioned on television or the radio. In discussing experimentation few texts mention failure. Nevertheless, printed in many other textbooks is the fallacy that, "The scientific method cannot be used by nonscientific personnel."

Nonscientific personnel can use the scientific method since this method is a thought process or a mental thought pattern. Examples to support my statement may be cited in political science and law enforcement. The Marshall Plan for economic rehabilitation is an outstanding example of a statesman's use of the method of science. Certainly, there was consultation and thought as to how this country could aid post-war Europe. Behind closed doors several hypotheses were expressed. The great experiment took place. One nation was experimenting with other nation's economy. It is sad that Secretary of State Marshall did not live to see the *outcome* or *conclusion*. In some future day, history books may record the *conclusion* for posterity to read and remember.

The Federal Bureau of Investigation supplies us with another instance of "the use of the scientific method by nonscientific personnel"—this time in the field of law enforcement. Agents in this arm of the law are highly

trained in *observation* of facial characteristics, crime scene details, terrain details, identification of dead persons, and weapons. There are personnel in this service that maintain files of statistics and fingerprints.(3) This is the *collection* of data step. Skilled personnel must operate the modern world-wide communications network. *Experimental* approaches are attempted. Chemical analysis of cloth, metal, and soil may be necessary. In this experimental approach to an *outcome* or *conclusion* trained chemists may assist law agents in interpreting laboratory results.

The Use of a Control

As a public school teacher one may not realize that he is using the scientific method. A guide may indicate step by step what is to be done. The author of your science "exercise" has thought out for you the necessary steps. You may even be gifted with a suggested conclusion to your "exercise." Remember, one is familiarizing "young minds" with a logical thought process. Students may need the author's initial guidance. Surely they will need yours. With this idea in mind, teachers should be on the lookout for textbook "guided" science exercises which erroneously picture experimental displays without controls. Your pupils may realize that controls are needed. Research laboratories use controls extensively. Valid conclusions cannot be reached when controls are mistakingly omitted.

Hidden between lines in a few textbooks for public school use is a discussion of an experimental control. For numerous biological and chemical *experiments* the results or *conclusions* must be compared with a control group and an experimental group. What is a control? One parallel test or a set of tests identical in all respects except one represents a control. Controls provide a standard of reference for evaluating the results of the experimental series.(4) In drug experiments, in classroom plant experiments, and in animal diet experiments, controls must be used. Biological controls are needed to keep the numerous variables constant. In a prominent laboratory, a biologist, quite upset, stated, "No matter how rigorously you control your experiment, organisms do as they . . . . well please."

Gibberellic acid is one of the components of a deadly fungus which for centuries has scourged the rice paddies of the Orient, causing the plants to grow to great heights and quickly die. For many years Japanese scientists had analyzed the fungus in their attempts to destroy it. During the years 1926-1938 the agent causing overgrowth was discovered and studied intensively. Because of World War II and the language barrier, news of these discoveries did not reach the outside world until 1950. Extensive gibberellic acid research was begun at Beltsville, Maryland, in 1955 and is continuing today.(5)

Turtox Biological Supply House, 8200 South Hoyne Avenue, Chicago 20, Illinois, distributes a free bulletin on "Experiments with Solutions of Gibberellic Acid" and offers for sale to teachers this powder at economical prices.

This photo shows a student evaluating a plant experiment. Notice the two control flower pots on the right. They are properly labeled, "control." Two experimental pots with visible plant growth are on the left. These four containers were kept in the same area of the laboratory. Similar seeds were used with the same soil weight as well as soil type. Measured amounts of gibberellic acid

solution were poured in the experimental pots periodically. At the same time *water only was poured in the control pots.* Notice the measuring cup for accurate measurements of acid solution and water.

Notice the student measuring plant growth with a yard stick Her conclusion will be expressed as a mathematical ratio. Here is an opportunity to apply mathematics throughout *observations.* At this stage the control seeds have not yet started growth.

Conclusion

Students should not be restricted and confined in their use of the scientific method, for it is merely a suggested habit of thought. For this reason all grade levels can be familiarized with this mental guide.

Flexibility in sequence of steps is essential and is practiced in laboratories.

This method is essential in problem-solving. Properly explained and interpreted, the scientific method becomes a reliable aid—ready to assist.

Millions are employed in each facet of the scientific method. The lifetime work of these people may be to make the next step possible for hundreds of other co-workers. The scope is boundless.

Our money makes *experimentation* possible where our health is concerned and where our military protection is necessary.

There is a trend toward replacing man's observations with instrumentation. This is significant in the *observation* step.

To many an obscure scientist, the *experimental* step has brought fame. Human interest stories in science literature frequently introduce chapters with accounts of historical experimentations.

The Nobel Prize is a world-wide award, an incentive for excellency in the use of the scientific method.

Progress in science in turn aids further scientific progress. Modern communications and travel enrich, improve, and inspire research.

Where controls are needed in the experimental step, they should be used to give valid *conclusions.*

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2. *Time,* October 19, 1959.
3. *The Story of the F.B.I.,* E. P. Dutton and Company, New York, 1954.
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1961 AIBS Meeting

**PURDUE UNIVERSITY,
WEST LAFAYETTE, INDIANA
August 28 to September 1, 1961**

CALL FOR PAPERS

The next meeting of the NABT will be held on the campus of Purdue University under the sponsorship of the AIBS. The chairman of the local committee is Dr. Joe Novak, Department of Biological Sciences, Purdue University.

Several joint sessions with other organizations concerned with teaching are currently being planned. The details of these will be included in later issues of the Newsletter or the ABT.

Members are invited to contribute papers for the general sessions on various aspects of biology teaching. Papers are particularly desired on the following topics:

1. Science fairs
2. Teaching devices
3. Methods of presenting specific topics.

Please forward titles to Dr. Clarence J. Goodnight, NABT Vice-president, Department of Biological Sciences, Purdue University, no later than May 1, 1961.

The following information, typed double space is requested.

1. Name of author and institution represented, including mail address.
2. Title of paper.
3. Projection facilities required.
4. Time required (not more than 15 minutes).

An Experiment in the Scientific Method

JOHN W. KLOTZ
Concordia Senior College, Fort Wayne, Indiana

Every good science teacher realizes that there is much more to his teaching than imparting facts and information. Indeed he recognizes that if he limits his efforts to this task, he is likely to destroy the students' interest in the subject he is trying to teach. Much more important than teaching facts is showing what science is about. This is especially important for the student who will not himself become a scientist but who will have to live with science and its products, and who as a citizen will have a voice in determining what funds are to be allocated to scientific endeavors, and in determining some of the directions science is to take.

One of the most important and least understood concepts in science is the scientific method itself. Many people have the idea that this is a magic formula that needs only to be followed carefully in order to gain success. It is a genie which if rubbed properly assures fantastic results. No doubt the development of the A-bomb during World War II and of the Salk vaccine more recently contributed to this misunderstanding. They were the results of a deliberate search for knowledge. Men, money, and materials were poured out freely, and success was achieved. Unfortunately a great many people have concluded as a result of these experiences that scientists with their scientific method need only men, money, and materials to accomplish any end. And they become very impatient when the scientist cannot quickly produce the magic results they expect of him.

It is especially important that attention be given to the scientific method in a science course so that these misapprehensions and misconceptions can be cleared up in the minds of the students. But can we do more than talk about the scientific method? Can we give our students some experience with it in an experiment which they themselves perform? We all realize that talking about any subject is not nearly so vivid as manipulating materials in connection with it. Indeed this is one of the reasons for laboratory work in science. It is highly desirable that any discussion of the scientific method be illustrated with some type of experiment.

Such an experiment was recently worked out by the author and five students, Edward Homeier, Dixie Mathis, Allan Oesterreich, Roy Pfund, and Richard Sandler. Four high school biology classes at Walther Lutheran High School participated and one eighth grade class at Grace Lutheran School. In each of these the project was directed by a student teacher. The materials chosen for the experiment were the puparia of *Sarcophaga bullata*, a blowfly. The puparia are about the size, shape, and color of a bean seed. They were obtained from Carolina Biological Supply Company, Elon College, North Carolina.

The author first discussed the project in detail with the student teachers and then turned it over to them to work out. The same general pattern was followed by all five, though each added some materials of his own. It was decided that a discussion should first be conducted as to the nature of the scientific method and that then the blowfly puparia should be passed out with the assignment that the pupils themselves gain as much information about them as possible.

In discussing the scientific method a number of points were to be brought out inductively.

1. There is no single scientific method, no magic formula which will automatically guarantee success. Actually the "scientific method" is a series of methods following a general pattern but differing in detail according to time and circumstances.

2. Science depends on facts which are revealed by observation. An experiment is really an observation under controlled conditions.

3. The scientific method is a method of solving problems related to the animate and inanimate world.

 a. The first step in problem solving is a clear statement of the problem.

 b. After the problem has been stated a tentative solution or answer is suggested.

This is called a hypothesis. In many cases a series of hypotheses or tentative answers are suggested.

c. Each tentative answer must be tested. Usually many tentative answers are discarded before one is found which seems satisfactory. Thus there are many false starts in science.

d. The experimental method is a method of testing hypotheses. To exclude factors other than those being tested requires a control.

e. An experiment must be planned and must be carried out according to the plan.

f. Careful records are essential. Even data which may at first appear irrelevant must be recorded.

g. If an experiment seems to support a given hypothesis, it should be repeated to make certain that a second trial still supports the hypothesis.

h. Only those conclusions should be drawn from an experiment which are actually discovered from the experiment itself.

i. A problem may be attacked in many ways. There is no one "right" way of solving a scientific problem.

4. Much scientific information can be gathered from the observations and experiments of others. Before beginning an experiment, the experimenter should gather as much data as he can from scientific books and periodicals. In the course of an experiment and in drawing conclusions these sources should be used as much as possible.

In presenting this material to the classes, all of the points were illustrated either from the history of science or from the students' own observations. For instance, one of the student teachers used the example of a candle flame going out when covered with a glass. Another student used the example of the cause of the common cold. Still another student teacher used the example of "a hammering noise in my father's automobile engine."

After the discussion was completed, the pupils were shown the puparia, were told they would be given a number of them, and would be expected to get as much information as possible about them. The pupils were told they might have additional puparia if they needed them for their experiment.

In the discussion that followed, the class drew up a series of principles to be followed in their experiments. One such series was as follows:

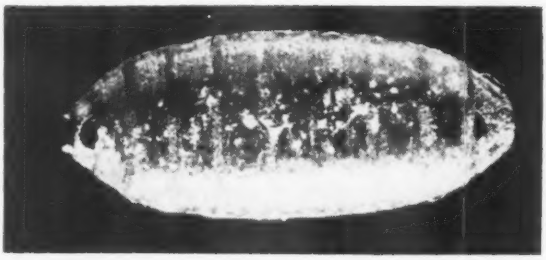

Figure 1. *Sarcophaga* puparium. Each puparium is about a half inch in length. (Courtesy Carolina Biological Supply Co.)

1. The puparia are not all to be used or tested in the same way. A series of hypotheses is to be explored, not just a single hypothesis.

2. It would probably be best to use at least two in each experiment.

3. As soon as some clue is gained as to the nature of what we have we should try to find additional information in books or scientific periodicals.

4. Observations should be recorded exactly. Failures and false starts must be recorded as well as studies which brought some success.

Since the problem assigned to the students was to get as much information as possible, it was to be expected that they would vary a great deal in their responses. Some were satisfied with a mere general identification. Others went on to a more exact identification. Some studied the puparia long enough for them to hatch. Others tried to keep the flies alive for a time. Some studied their food preferences. Still others tried to breed them. The result of the study of one class is given in Table 1.

A grade was assigned to each report on the basis of clarity of statement of the problem, planning of the experiment, amount of information gained, use of source material, and number of hypotheses tested.

The experiment aroused a great deal of interest in the pupils and seemed to help them understand the nature of the scientific method. It helped clarify the concept of many hypotheses and many false starts in science. It brought out the importance of accurate records. It emphasized that there are various methods of attacking a given problem. The

only concept not well illustrated by the experiment was the importance of a control. Even so, some of the pupils used controls. For instance, some pupils heated some puparia and kept others at room temperature. Others applied artificial light to some for twenty-four hours a day and kept others as a control. The chief defect of the experiment was the time it took to complete it. In order that some of the puparia might hatch and that there might be ample time for observation, pupils' reports were not collected for six weeks. This, however, was not a serious defect since the scientific method is a concept that is to be taught continuously not just casually referred to at the beginning of a course and then dropped.

TABLE 1

Summary of Pupil Observations and Procedures

Technique	
Planted	15
Burned	2
Fed and observed over a longer period of time	2
Put in water	12
Used magnifying glass	2
Watched hatch	4
Procedure	
Dissected	14
Observed only	7
Used resource material	24
Clearly stated hypothesis	12
Recorded data completely and accurately	13
Conclusion	
Arthropod	16
Insecta	19
Diptera	17
Blowfly	1
Housefly	7
Others: Botfly, Horsefly, "Bottlefly"	

Student Research

The best place to introduce student-conducted research into the educational curriculum is in high school, a Columbia University zoologist believes. Dr. Robert W. Merriam declared present laboratory instruction of biology "eliminates every creative vestige" by being too highly organized and by giving the student too explicit directions.

"Is it possible that we are organizing such qualities as independence, imagination, or ingenuity out of existence in the name of efficiency?" he asked.

"Biology, as any science, should be motivated largely by educated curiosity about natural phenomena. Motivation in the negative sense through the prod of impending examinations . . . is not enough. . . .

"Curiosity does not just happen; one must have the opportunity to become aware of phenomena, the knowledge and the orientation to appreciate them when seen," Dr. Merriam said.

While many opportunities for creative laboratory work exist, Dr. Merriam said these customarily are bypassed, and only routine observation and measurement techniques are taught.

"Students are expected to observe the expected, master the method, turn the dials, or follow the recipe to produce the 'desired' results," Dr. Merriam commented.

He added that "it is common knowledge" among biology teachers that at both high school and college (undergraduate) levels "students respond with great interest to the challenge of the unknown."

Selection of appropriate problems would be crucial, the scientist said. Problems should be sought which can be attacked by asking a simple question, and preferably by using living organisms, he believes.

Good questions would be conceived so that the student could best get an answer by imposing variables and making quantitative measurements. The answer could be referable to a generalized biological concept.

Examples of possible high school research problems, Dr. Merriam suggested, might be:

How good is an experimental diet in comparison with a varied human diet as measured by the growth rate of cockroaches?

How does a scout of an ant colony communicate to others of the colony the location of a food "find"?

Or, how do the visible populations of one square yard of sunlit meadow respond when a situation of total shade is imposed upon it?

Dr. Merriam said experiments of this sort could be integrated into conventional high school biology with only a small reduction in the time now allotted to other matters.

Book Reviews

MODERN BIOLOGY, Truman J. Moon, James H. Otto, Albert Towle, 758 pp., $5.60, Henry Holt and Company, New York, 1960.

This is the latest edition of one of the most popular biology texts in the history of education. This latest revision is not a radical one although some features have been added. Thus, it seems rather unnecessary to review this fine text in any great detail since it is so widely known to most biology teachers. Yet, it seems obvious that some critical attention be given it if only to critically examine much of secondary school biology teaching. The new features are a greater use of color diagrams and pictures, chapters on radiation biology and space biology, and some revision of some of the textual material.

As most teachers know, the chief feature is the organism approach which has been labelled the phylogenetic approach by some. Taxonomy is featured in that organisms are taken up one by one, group by group. Physiological principles are taken up in connection with each one. There are some interrelating units such as conservation, genetics, ecology, disease, and cell biology. Some biologists make elaborate critical remarks about specific statements in the text, but on close inspection most of these turn out to be differences of opinions and approach as well as inference. The book has a deserved popularity.

But the reasons for this popularity must rest on an important fact—it reflects the way much of American biology is being taught and organized. And to this point must the chief critical remarks be made. Should the biology course be encyclopediac? Should secondary school biology emphasize an overwhelming variety of terms and names? Should there be such an emphasis on a great variety and all-inclusive listing of terms and concepts? Should the ideas of evolution be introduced without using the term evolution? These are the features of much current biology teaching, and this text reflects them. If there are teachers and biologists who disagree with these features, then their criticisms should not be aimed primarily at the text, but the courses and the teachers. Yet, while this is a secondary school text, much that applies to it, critical or complimentary, can also be applied to *many* college level texts, and presumably college-level courses.

TEACHER'S MANUAL AND ANSWER BOOK FOR MODERN BIOLOGY, Truman J. Moon, Elizabeth H. Crider, 124 pp., Holt, Rinehart and Winston, New York, 1960.

TESTS IN BIOLOGY, James H. Otto, Sam S. Blanc, Elizabeth H. Crider, Henry Holt and Company, Inc., New York, 1960.

BIOLOGY INVESTIGATIONS, TEACHER'S EDITION, James H. Otto, Sam S. Blanc, Albert Towle, 312 pp., Henry Holt and Company, New York, 1960.

These are the supplementary teacher materials for the well-known text by Moon, Otto, and Towle. They have had rather extensive revision over the previous similar materials.

The Teacher's Manual lists the answers to all the questions in the text. In addition there are teaching aids for each chapter and unit. Included also are film suggestions for each unit. The appendix takes up lists of laboratory equipment, laboratory technique suggestions, and student project titles.

Tests in Biology are mostly of the short answer type. Final tests for each semester are also included. New feature is the inclusion of essay questions for each test.

Biology Investigations represents a concerted effort of the authors to make this "workbook" more than a blank-filler. Included is a cut-out manikin for student use, a really novel feature. The appendix lists useful information like word origins, student project descriptions, and laboratory material lists. Each exercise is labeled, "Investigation," and consists of diagrams, graphs, tables, and drawings with appropriate introductory materials. There *are* blanks to fill in. Laboratory work is emphasized. The authors have made a real attempt to earn the title for each exercise as an "investigation."

LABORATORY MANUAL IN PRINCIPLES OF BIOLOGY AS ILLUSTRATED BY ANIMALS, Howard J.

Stains, 127 pp., $2.50, Burgess Publishing Co., Minneapolis, Minnesota, 1961.

This laboratory manual uses the workbook approach to laboratory study. There are questions to be answered, blanks to be filled, sketches and drawings to be made, and drawings to be labeled. There are fifteen exercises, and the author states that, "In general, each exercise can be finished in two hours." Certainly the exercise on the animal phyla covering 42 pages must be an exception. Other exercises are fairly standard approaches to the use of the microscope, mitosis, genetics, tissues, and the like. There are six exercises on mammalian organ systems based on the fetal pig.

John M. Hamilton
Park College, Parkville, Missouri

THE MARINE FISHES OF RHODE ISLAND, B. L. Gordon, 136 pp. $4.00, Book and Tackle Shop, Watch Hill, Rhode Island, 1960.

Mr. Gordon has aimed his book at several audiences with different interests and has hit none of the targets. The foreword states that the book is intended "as a valuable source of information for fishermen, boy scouts, nature-lovers, students, teachers, marine biologists, and naturalists." A book which satisfies the specialist is not usually of great use to the uninitiated and vice versa. This is one of the unfortunate facts of modern science but that is the way the cookie crumbles.

The student who wishes to learn the Rhode Island marine fishes will find no keys to identification, no suitable illustrations, and no drawings. The description of outstanding key characters is likewise omitted. Neither will those interested in natural history find comprehensive information on reproductive habits, migrations, growth, sex differences, etc. In essence, the book lists 215 fishes as to family, genus, and species with a short discussion of their economic importance, and a general statement about the method of capture, size, abundance, and places where each species has been taken.

The author has obviously not been guided by an experienced taxonomist. Some of the species names are out of date, and many of the common names would not be recognized outside New England. He has not followed the nomenclature adopted by the American Fisheries Society and which appears as their Special Publication Number 2, 1960, "A List of Common and Scientific Names of Fishes from the United States and Canada."

This publication is intended to standardize the common names of North American fishes and to provide a comprehensive listing of the scientific names as well.

The book is attractively bound, is printed on good quality paper with easily read type, and includes an index to both common and scientific names.

Shelby D. Gerking
Department of Zoology, Indiana University

A FIELD LIST OF BIRDS OF THE DETROIT-WINDSOR REGION, Ralph A. O'Reilly, Jr., Neil T. Kelley, Alice H. Kelley, 39 pp., $.50, Cranbrook Institute of Science, Bloomfield Hills, Michigan, 1960.

A small, well-done booklet which is a record of the abundance of many bird species during each month of the year. This is presented in tabular form with a handy blank for each page for the reader to record his own observations. There are instructions for the birdwatcher and an excellent listing of recommended places to observe birds in the Detroit region. It is the result of a ten year critical study.

P. K.

ECOLOGY OF INLAND WATERS AND ESTUARIES, George K. Reid, xvi + 375 pp., $7.80. Reinhold Publishing Corporation, New York, 1961.

Prof. Reid has written an excellent textbook on the ecology of inland waters and estuaries. He treats his subject at an elementary level but goes beyond many limnology books in that streams, rivers, and estuaries are thoroughly covered along with his discussion of the ecology of lakes. The book consists of fourteen chapters divided into five sections. The first three sections, devoted to the physical aspects of the inland waters as environments for plants and animals, cover the origins of lake basins and stream and estuary channels, the nature of water, and the physical and chemical aspects of natural waters as an environment. The last two sections include a brief discussion of each of the major groups of protists, plants, and

animals found in inland waters and two chapters on the relationships of organisms and environment.

There is an extensive bibliography, but there are few citations in the text. The author defends this by the statement that citation of sources "detracts from the readability, particularly at the introductory level." It is the opinion of the reviewer that one should teach prospective scientists, even at the introductory level, to expect to find and to use citations to original sources in their reading. The student who wishes to go deeper into a subject may have a hard time finding a useful reference in the seventeen page bibliography arranged alphabetically by author.

Many teachers will feel that at this level an ecology course should include marine and terrestrial environments, but certainly the student who has had a course based on this book would have little difficulty in applying ecological principles to other kinds of communities.

John M. Hamilton
Park College, Parkville, Missouri

THE FUTURE OF MAN, P. B. Medawar, 128 pp., $3.00, Basic Books, Inc., New York, 1960.

A small book containing the lectures of this British Nobel Laureate over the BBC. The topics are especially pertinent as they concern demography as seen by a human biologist. He proudly indicates that he wanted to raise questions rather than answer them. The questions he raises are concerned with human genetics as applied to population problems with beautiful illustrative examples. The author's knowledge of immunology makes the illustrations he employs especially meaningful. This is recommended for recreational reading, but that is primarily because it is so well written. It can also be easily recommended for the general biology student as a clear exposition of human biological problems involved in population studies.

P. K.

THINGS TO DO IN SCIENCE AND CONSERVATION, Byron L. Ashbaugh and Muriel Beuschlein, 163 pp., $2.50, The Interstate Printers and Publishers, Inc., Danville, Illinois, 1960.

The title is self-explanatory for this book, but it is primarily for junior high and lower secondary school classes. There are clear instructions for a great many demonstrations and student activities. A bibliography is attached to each chapter and at the end of the book.

Perhaps the chapter titles may be helpful: Space, Air, Sun, Soil, Water, Minerals, Plants, Animals, Electricity, Synthetics, and Nuclear Energy. These are divided into sections on specific concepts with appropriate demonstration suggestions.

The authors have done a fine job on a task which was needed for some time. Teachers have longed for some time to have these helps and suggestions, and they will be indebted for the fine way in which the authors have written. The illustrations are disappointing.

P.K.

FALLOUT: A STUDY OF SUPERBOMBS, STRONTIUM 90 AND SURVIVAL, John M. Fowler, Ed., $5.50, Basic Books, Inc., New York, 1960.

Written by a series of noted authorities on various aspects of radiation and its damage, this book will be a powerful weapon in itself to use in teaching the biological implications of a nuclear war—or nuclear explosions in peace time for that matter. A foreword by Adlai Stevenson is a thoughtful statement of the political implications of the facts brought out in the volume, but the real message is in the sober analysis of data by the scientists writing in this book. Yes, there are some alarming biological effects of radiation, and this book can be used as an easy to read source of the facts which are known about this. Biology teachers must read this if they have not read extensively elsewhere in this field. P.K.

FRONTIERS OF THE SEA, THE STORY OF OCEANOGRAPHIC EXPLORATION, Robert C. Cowen, 307 pp., $4.95, Doubleday & Company, Inc., Garden City, New York, 1960.

An absolutely fascinating book about oceanography. This field of science with its rapidly expanding dimensions and its unusual blend of many disciplines is the subject of the book told in an easy style yet crammed full of information. The geological side of the oceans and seas, physical, chemical, and historical dimensions, is told in several chapters. Then

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the author tells of recent discoveries as a result of IGY. The biological side of oceanography is not neglected but told in its modern aspects with beautiful illustrations. The concluding chapter concerns the future of oceanography and its needs.

If the reviewer has used many superlatives, it is because he carefully weighed their use. It is a book for the general reading shelf as well as the biology classroom. Schools along the marine environment may find many suggestions for further study. And inland schools will find student and teacher appetites alike whetted for a visit to the sea. It is a handsome book and well worth the money. It will rank with *The Sea Around Us* as a modern supplement to bring the reader up to date about this fascinating subject.

P.K.

Man High, Lt. Colonel David G. Simons, Don A. Schanche, 262 pp., \$4.50, Doubleday & Company, Inc., Garden City, New York, 1960.

An account of the 1957 balloon flight into space by Lt. Col. Simons recommended for the school library. This is the type of work librarians are looking for which has the dual purpose of recreational reading as well as some good, factual knowledge. And the subject itself—space travel—makes it a natural. Biology teachers will be interested in examining this book as the author emphasizes throughout the effects of space travel on organisms including man. It is interesting to read about the direction of research in space biology which this book reveals. Although it doesn't look at first appearance as a good recreational reading book for biology students, examination will reveal that it really is a good book for this purpose. And it is an account of an actual occurrence.

P. K.

The Wonder of Light, Hy Ruchlis, 154 pp., \$2.95, Harper & Brothers Publishers, New York, 1960.

For junior high school students, this appropriately illustrated book attempts to digest and tell in an interestingly descriptive manner, the theories of light transmission, the character of light itself, the spectrum, optics, and some thought provoking questions and experiments. The author succeeds in his purpose admirably. For the general science shelf.

P.K.